ERDC/CERL TR-03-23

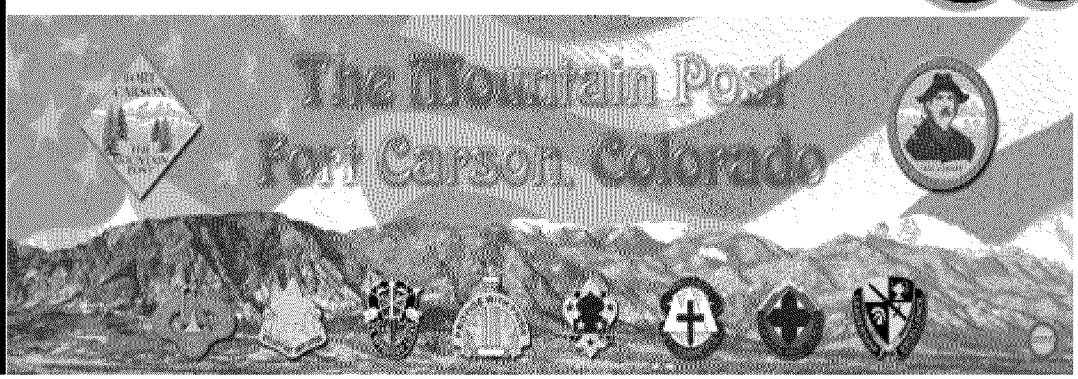
US Army Corps of Engineers®
Engineer Research and Development Center

Process Optimization Assessment

Fort Leonard Wood, MO and Fort Carson, CO

Mike C.J. Lin, John L. Vavrin, Walter Smith, and Clay Conner

November 2003



Construction Engineering Research Laboratory

ERDC/CERL TR-03-23
November 2003

Process Optimization Assessment: Fort Leonard Wood, MO and Fort Carson, CO

Mike C.J. Lin and John Vavrin

Construction Engineering Research Laboratory
PO Box 9005
Champaign, IL 61826-9005

Walter Smith and Clay Conner

Energy Technology Services International, Inc.

Final Report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit # CFE-X302

ABSTRACT: This work performed a Process Optimization Assessment (POA) on behalf of Fort Leonard Wood, MO and Fort Carson, CO to identify process, energy, and environmental improvements that could significantly improve the installation's mission readiness and competitive position. A Level I assessment assumes that technical solutions are possible and that economics are approximations. No engineering measurements are made. The existing process is challenged, and new practices and new technologies are considered. A Level I assessment would normally be followed by a Level II process audit (an in-depth analysis in which all assumptions are verified), which would result in a group of "appropriation grade" process improvement projects for funding and implementation.

This work quantified 26 Energy Conservation Measures (ECMs) at Fort Leonard Wood, which, when implemented, will reduce the post's annual energy and operating costs by approximately $1,963,275 for a capital investment of approximately $1,929,300, yielding an average simple payback of 1 year. When implemented, the 29 ECMs quantified at Fort Carson will reduce that installation's annual energy and operating costs by approximately $2,117,250 for a capital investment of approximately $1,250,300, yielding an average simple payback of 0.6 yr.

Contents

List of Figures and Tables

Figures

Tables

Conversion Factors

Non-SI* units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Système International d'Unités ("International System of Measurement"), commonly known as the "metric system."

Preface

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 4A262784AT45, "Energy Technologies Applied to Military Facilities"; Work Unit CFE-X302, "Industrial Energy Assessment." The technical monitors were Allen Simpson, Fort Leonard Wood, and Scott Clark, Fort Carson.

The work was performed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was John L. Vavrin. Appreciation is owed to Allen Simpson (Fort Leonard Wood) and Scott Clark (Fort Carson) for their coordination and support. Walter Smith and Clay Conner are associated with Energy Technology Services International, Inc. (ETSI), which provided consulting support. Dr. Tom Hartranft is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The technical editor was William J. Wolfe, Information Technology Laboratory. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

Most Department of Defense (DOD) manufacturing and maintenance technologies are based on techniques developed 20 to 50 years ago. These processes were designed prior to three major constraints imposed in today's society: high energy costs, costs of environmental compliance, and lower operating budgets. Although relatively insignificant in the past, today the high energy and environmental compliance costs can drive the cost up unacceptably—and even close down an operation. Older processes were not designed to meet these unanticipated changes. Competition has stimulated commercial industries to adapt to the new requirements, but Federal government facilities have been slow to adapt for a number of reasons. Passage of the Federal Facilities Compliance Act has provided new impetus for process improvement and pollution control.

To meet the challenge, the DOD has set goals for both reductions in energy use and pollution generation. Executive Order 13123 Section 203 directs all Federal industrial and laboratory facilities to reduce energy consumption per sq ft, per unit of production, or per other unit as applicable, by 20 percent from 1990 to 2005. That figure was further increased to 25 percent by 2010. No facilities will be exempt from these goals unless they meet new criteria for exemptions. Additional legislation requires the Defense Department to:

1. Reduce the use of energy and related environmental impacts by promoting renewable energy technologies.
2. Show a 50 percent reduction in toxic chemical and pollutant releases to the environment
3. Incorporate waste prevention and recycling in everyday operations
4. Acquire and use "environmentally preferable" products and services to the maximum extent possible
5. Periodically modify procurement guidelines to incorporate the latest USEPA guidance.

These goals cannot be met by focusing solely on energy generation methodology or waste treatment techniques. An overall understanding of material demand and waste generation, without altering the basic production process, is required to meet these goals.

During the past few years, the U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (ERDC/CERL) has been involved in process and energy optimization to assist DOD installations in meeting energy efficiency and environmental compliance requirements. The "Process Optimization" (PO) Audit extends conventional energy and environmental auditing into the manufacturing processes. Several useful tools have been developed to collect process and environmental data and to conduct comprehensive facility and process energy/emission analyses.

A Level I process audit is a 2- to 5-day walk-through effort to identify the dollar potential for process improvements to the bottom-line. This process assumes that technical solutions are possible and that economics are approximations (±40 percent). No engineering measurements are made. The process audit uses brainstorming techniques to create a new process by modifying the existing (old) process. The existing process is challenged, and new practices and new technologies are considered. A Level I Audit would normally be followed by a Level II process audit to verify the Level I assumptions and to more fully develop the ideas from the Level I screening analysis. A Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished for $80,000–$150,000 over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which all assumptions are verified. The end product from Level II is a group of "appropriation grade" process improvement projects for funding and implementation.

The key elements that guarantee success from a PO Audit are: (1) the involvement of key facility personnel who know what the problems are, where they are, and have thought of many solutions; (2) the facility personnel sense of "ownership" of the ideas, which in turn develops a commitment for implementation; and (3) the PO audit focus on site-specific, critical cost issues which, if solved, will make the greatest possible economic contribution to facility's bottom-line. Major cost issues are: capacity utilization (bottlenecks), material utilization (off spec, scrap, rework), labor (productivity, planning/scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art), etc. From a cost perspective, process capacity, materials, and labor utilization are far more significant than energy and environmental concerns. However, all of these issues must be considered together to achieve DOD's mission of military readiness in the most efficient, cost-effective way.

Objectives

The objective of this project was to identify opportunities for process energy efficiency improvements and reductions of pollutant emissions at Fort Leonard Wood and Fort Carson, using the process energy and pollution reduction (PEPR) methodology and the process optimization guide, both of which are tools developed by CERL with Energy Technology Services International, Inc. (ETSI).

Approach

This work involved the following steps:

1. Installations willing to participate in the process were identified and contacted.
2. A pre-assessment site visit was held and mutually agreeable time and processes targeted for review were determined.
3. A 1-week Level-I energy optimization audit was conducted employing expert consultants:
   a. Conduct one-half-day meeting with base energy/environment/process operation staff to introduce the process energy optimization (PEO) approach (Figure 1) and to develop utility one-line balances for base utilities.
   b. Identify opportunities in selected processes to improve performance and to increase efficiency and reduce energy and emissions at Fort Leonard Wood included:
      (1) The heating plants in buildings No. 2351, 2369, and 1021
      (2) The laundry operation
      (3) The DOL maintenance complex with specific focus on paint/blast, wheeled vehicle shop and heavy shop.
   c. Identify opportunities in selected processes to improve performance and to in-crease efficiency and reduce energy and emissions at Fort Carson include:
      (1) The heating plant in buildings No. 1860
      (2) The heating system in building No. 8000
      (3) The DOL maintenance complex with specific focus on paint/blast and component re-build (CRB).
   d. Develop potential cost savings and preliminary capital investment from process optimization improvement.
   e. Conduct Debrief Session on final day of onsite work.
   f. Document results in final reports.
4. Findings were gathered and analyzed, and recommendations were formulated.
5. Plans were made to monitor the implementation of the Level I recommendations.

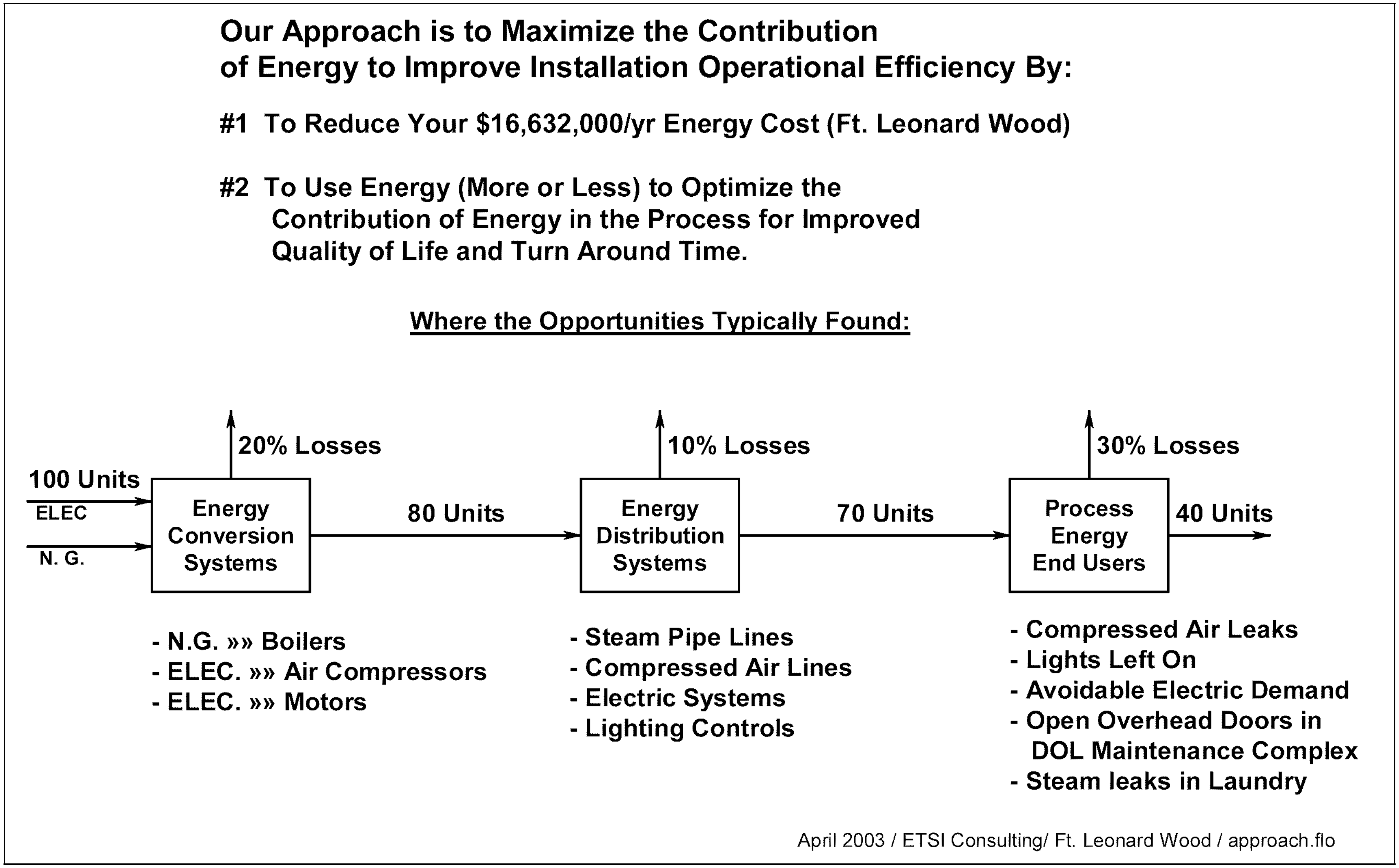


Figure 1. Approach to process energy optimization at Fort Leonard Wood.

Scope

This Level I effort identified process, energy, and environmental improvements that could significantly improve the installation's mission and competitive position. A Level I study assumes that technical solutions are possible and that economics are approximations (±40 percent). No engineering measurements are made.

Mode of Technology Transfer

The information derived from this work will be submitted to the two installations studied. It is anticipated that the results of this work will contribute to further awareness of Corps, District and Army installation personnel, via implementation through associated regional Installation Management Agency (IMA). It is also planned to disseminate this information through workshops presentations and professional industrial energy technology conferences.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 The Process Optimization Assessment at Fort Leonard Wood

Site Overview

The history of Fort Leonard Wood dates back to the dark days just before World War II. By 1940, war had engulfed Europe and much of Asia. One of the major challenges was finding suitable training areas for the expanding Army. In 1940, the War Department decided to establish a major training facility in the Seventh Corps area. This command comprised most of the states of the central plains. Originally located near Leon, IA, the site for the new training center was moved to south-central Missouri. In the first days of December 1940, military and state officials broke ground for what was known as the Seventh Corps Area Training Center. In early January 1941, the name was changed to Fort Leonard Wood. The post is named for Major General Leonard Wood, a distinguished America warrior and a surgeon, Leonard Wood graduated from Harvard University and began his military service as a contract surgeon during the Apache Indian Wars in the 1880s. Leonard Wood was the Army's Chief of Staff from 1910 to 1914.

Building a major training center in the rugged terrain of the Ozarks presented a formidable challenge. Fort Leonard Wood had to be built from scratch, and the first troops were scheduled to arrive in only a matter of weeks after the initial groundbreaking. In 6 months, they had built nearly 1600 buildings, comprising more than 5 million sq ft of floor space, at a cost of $37 million. Originally, Fort Leonard Wood was to be the home of the 6th Infantry Division. In time, four other infantry divisions—the 8th, the 70th, the 75th, and the 97th trained at the installation. In addition, a number of non-divisional units, ranging from field artillery battalions to quartermaster companies, also trained on the post. During World War II, more than 300,000 soldiers passed through Fort Leonard Wood on their way to service in every theater of operation.

In 1985, the Secretary of the Army announced the U.S. Army Engineer School would move from Fort Belvoir, VA, to Fort Leonard Wood. The Engineer School completed its move in 1988, occupying a new $60 million state-of-the-art training and education facility. For the first time in nearly 50 years, all engineer training—including officers, warrant officers, noncommissioned officers and enlisted

personnel—would take place at the same location. The growth of the post brought even more construction, with new commissary, fitness, and training facilities. The end of the cold War did not result in a decline in activity at the post. The invasion of Kuwait by Iraq prompted a significant military response by the United States and its allies. Fort Leonard Wood units deployed to Southwest Asia for operations Desert Shield and Desert Storm. In addition, the installation processed more than 4,000 Reserve component soldiers mobilized in response to the Iraqi invasion. This included 16 Army Reserve and nine National Guard units. Fort Leonard Wood also provided personnel and technical expertise to contingency and humanitarian operations in Somalia, Haiti, and Bosnia. Post Cold War training also included the resumption of Navy, Air Force and Marine Corps personnel instruction in Engineer construction techniques at Fort Leonard Wood.

The most recent development for Fort Leonard Wood has been its selection as the new home of the U.S. Army's Chemical and Military Police schools. Under the provisions of the Base Realignment and Closure Act, the Department of the Army, with the concurrence of the U.S. Congress, decided in 1995 to close Fort McClellan, Alabama. The two Fort McClellan schools—Chemical and Military Police—were directed to relocate to Fort Leonard Wood by the end of the 20th Century. This brought yet another significant building effort to the post, as new facilities were begun to house the two schools and provide the specialized training unique to each branch. The move to Fort Leonard Wood was completed in 1999. Now designated the Maneuver Support Center, Fort Leonard Wood enters the new century and the new millennium as a state-of-the-art, diversified training center in service to the United States of America.

Fort Leonard Wood is located in Pulaski County, south central Missouri, and covers more than 65,000 acres. Bordering the installation to the north are the towns of Waynesville and St. Robert, with an estimated combined population of 4,937. St. Louis is a two-hour drive to the east along I-44. All chemical, engineer and military police soldiers, plus many marines, airmen, sailors, coast guardsmen, and international students from allied nations receive training at Fort Leonard Wood and the U.S. Army Maneuver Support Center. The post is also the home of the 3rd Training Brigade, where thousands of new recruits receive their basic training every year.

Analysis of Energy Supply, Consumption, and Costs

In 2002, Fort Leonard Wood consumed 176,800,000 kWh with an annual average load of 20,200 kW at 3.98¢/kWh, for a cost of $7,032,000. During the same pe-

riod, the installation used 1,008,300 MMBtu of fuels that cost $9,600,000 at an average cost of $9.52/MMBtu. For the entire year Fort Leonard Wood spent approximately $16,632,000 for energy.

The plant energy systems convert the kWh of electricity and Btu of fuel into various productive utilities such as compressed air, steam, and shaft power to support end uses. These annual purchased energy costs and variable unit costs are used as the cost basis of savings for the economic analysis of Energy Conservation Measures (ECMs). Table 1 lists a breakdown of purchased electricity and fuel by end user and the cost basis for each.

Summary of Results

Dozens of ECMs were identified for the following plant utility systems; Post-wide (PW), Heating Plant (HP), Laundry (L) and Maintenance Complex (MC). A total of 26 of the ECMs were economically quantified and, when implemented, will reduce the post's annual energy and operating costs by approximately $1,963,275. The capital investment required to accomplish these savings is approximately $1,929,300 and results in an average simple payback of 1 year. Chapter4 of the report for a detailed discussion of results.

Table 1. Breakdown of purchased electricity and fuel by end user.

Electricity	k$/yr	% total	Fuel	k$/yr	% total
1. Family Housing	$1,897	27.0%	1. Family Housing	$2,190	22.8%
2. Miscellaneous Other	$1,844	26.2%	2. 600/700/800 Complex	$1,460	15.2%
3. Training Barracks	$800	11.4%	3. CDTF, HQ, Other	$1,460	15.2%
4. Hospital	$773	11.0%	4. B-1021 Heating Plant	$1,280	13.3%
5. Specker Barracks	$557	7.9%	5. LP Tanks (Post-wide)	$1,060	11.0%
6. DOL Maintenance Complex	$350	5.0%	6. B-2369 Heating Plant	$875	9.1%
7. Retail Center	$165	2.3%	7. B-311 Hospital	$820	8.5%
8. B-2369 Heating Plant	$146	2.1%	8. B-2351 laundry boilers	$350	3.6%
9. NCO Academy	$140	2.0%	9. Laundry dir. fired dryers	$105	1.1%
10. Mansen HQ	$140	2.0%	Total	$9,600	100.0%
11. B-1021 Heating Plant	$130	1.9%	Unit cost basis of savings:		
12. Soldier Service Center	$52	0.7%	a.) Electricity@3.98¢/kwh (incl.$6.18/kW-mo)		
13. Laundry	$38	0.5%	b.) Natural gas @$11.00/MMBtu		
Total	$7,032	100.0%	c.) Propane @ $0.70/gal or $7.80/MMBtu d.) No. 2 FO @ $0.68/gal or $5.25/MMBtu c.) Water @ $0.73/kgal d.) Sewer @ $0.38/kgal		

No Cost and Low Cost ECM Highlights

The economic analyses of the ECM results appear to be outstanding. Table 2 lists eight of the ECMs that can be implemented at no or low cost for a total annual savings of $1,161,500.

Capital Project ECM Highlights

Table 3 shows 18 of the ECMs that require a capital investment with excellent paybacks. The total annual savings for the combined list equals $1,456,200 with an installed cost of $1,925,300 and a simple payback of 1.3 years.

Comments on Overall Audit Results

The total savings and cost figures shown above can be somewhat misleading. The actual total of $2,617,700 represents the summation of ECMs that have been evaluated and calculated independently of each other. Also, the estimations that are used to develop each ECM are assumed to be accurate at plus or minus 20 to 40 percent. Finally, the benefit of one ECM may be diminished if another is done because they have interrelated kWh and/or fuel savings.

Table 2. No cost and low cost ECMs.

ECM#	Energy Conservation Measure (ECM)	Category (SD, LU, etc)	Net Savings (k$/yr)	Capital Cost (k$)	Simple Payback (yrs)
PW-01	Optimize use of lowest cost fuel, post-wide	SD	$1,019.0	$0.0	Immed.
HP-07	Optimize HW temperature set point for HP#1021	SD	$48.1	$0.0	Immed.
HP-05	Optimize HW temperature, set points for HP#2369	SD	$52.0	$0.0	Immed.
L-02	Repair 15% of traps and replace 15% of 122 traps	LU	$28.8	$0.0	Immed.
PW-03	Replace standard V-belts with COG type V-belts to save 2% of motor load	LU	$10.0	$0.0	Immed.
L-04	Repair 5gpm leak on air compressor cooling water	LU	$1.8	$0.0	Immed.
HP-04	Optimize 100psi steam to meet warm weather HP #2351 requirements	SD	$1.0	$0.0	Immed.
MC-05	Identify and repair compressed air leaks in WV and HS areas	LU	$0.8	$0.0	Immed

Table 3. Capital project ECMs.

ECM#	Energy Conservation Measure (ECM)	Category (SD, LU, etc)	Net Savings (k$/yr)	Capital Cost (k$)	Simple Payback (yrs)
HP-06	Adjust barracks window opening to meet ventilation requirements	CP	$280.0	$120.0	0.4
L-01	Install VFD on extractor motor to optimize extractor cycle time for a 5% increase in output	CP	$100.0	$75.0	0.8
MC-04	Initiate predictive/preventative maintenance to reduce TAT	CP	$135.0	$150.0	1.1
HP-02	Insulate 50ft of 10 inch diameter “bare” steam pipe in Heating Plant #2351	CP	$43.2	$33.8	0.8
HP-10	Install VFD on 30hp combustion air fan in HP#1021	CP	$39.0	$37.5	1.0
PW-05	Develop long term metering plan	CP	$140.0	$140.6	1.0
MC-06	Re-engineer tail-pipe suckers in heavy shop that do not work properly.	PET	$13.4	$13.4	1.0
L-03	Insulate all bare pipes, valves, etc. w/ soft cover snap on insulation	CP	$7.2	$8.0	1.1
HP-09	Install VFD on 60hp HW recirculation pumps in HP#2369	CP	$20.4	$24.0	1.2
HP-11	Install VFD on 75hp HW recirculation pump in HP#1021	CP	$11.0	$15.0	1.4
MC-02	Analyze the entire HVAC system including: system supply problems, air side balance and controls	CP	$335.0	$550.0	1.6
MC-01	Upgrade lighting in paint booth to reduce turn around time (TAT)	CP	$3.5	$5.0	1.4
HP-08	Install VFD on 20hp combustion air fan in HP#2369	CP	$45.1	$70.0	1.6
PW-04	Insulate and repair leaks on all justifiable steam and HW systems, post-wide underground distribution systems	CP	$215.0	$430.0	2.0
PW-02	Add shut-off controls to all air compressors that are left on when not needed.	CP	$27.4	$100.0	3.7
HP-01	Install VFDs on 10hp combustion air fan in Heating Plant #2351 (laundry)	CP	$13.2	$33.0	2.5
HP-03	Install “in-stack” economizer to heat boiler feed water for Heating Plant #2351	CP	$13.4	$34.0	2.5
MC-03	Replace high traffic overhead doors and seals to greatly reduce building heating loads.	CP	$14.4	$90.0	6.3

The research team has found that, based on more than 100 PEO audits, on average the “net” or real anticipated savings from all of the ECMs developed is approximately equal to 75 percent of the “gross” savings from a typical audit. This means that of the $2,617,700 in savings that have been calculated with less than a 3-year payback in the audit, approximately $1,963,275 ($2,617,700 x 0.75 =

$1,963,275) in actual savings will come from implementing these ECMs. As a result, further engineering analysis and cost estimating are highly recommended. Nevertheless, the overall economics from the ECMs presented indicate great potential for excellent ECM paybacks.

Audit Team and Master Audit Schedule by Team, Location, and Hour

The Fort Leonard Wood POA took place over a 5-day period between Monday, 2 April and Friday, 25 April 2003. Table 4 lists participants in the POA. Figure 2 shows the Master Audit Schedule below how the onsite time was organized by team, activity, location and hour. The purpose of the schedule was to provide a framework for the team to follow and make sure that all of the critical areas in the scope of work were covered.

Table 4. Fort Leonard Wood POA audit participants (19-23 April 2003).

Name	Work area
Lloyd Allen	DOL-Maintenance Division
Earl Bivens	DPW-Ops Branch
Clark Blankenship	DOL-Maintenance Division
Sam Burnell	Supply
Richard Cole	DPW
Thomas Dalrymple	Garrison Command
Chick Dutton	DOL-Maintenance Division
Tony Easter	DOL-Maintenance Division
Larry Guffey	DOL-Maintenance Division
Richard Hope	DOL-Maintenance Division
Danny Kuhn	Heating Plant
Terry Luttrell	DOL-Maintenance Division
Scott Murrell	DPW
Louis Pappas	CMD Group
Jim Penn	Laundry
Allen Simpson	DPW-Energy Mgmt
Dennis Taylor	Laundry
Chet Thomas	DOL-Maintenance Division
Tim Townsend	DOL-Maintenance Division
Brad Vance	DOL-Maintenance Division
Jimmy Walton	DOL-Maintenance Division
Dale Wyant	DPW-Electrical
Mike Lin	CERL
Walt Smith	ETSI Consulting
Clay Conner	ETSI Consulting

Day 1 Monday, April 21	Day 2 Tuesday, April 22	Day 3 Wednesday April 23	Day 4 Thursday, April 24	Day 5 Friday, April 25
(0630 – 0730) ETSI tour of process	**(0630 – 0730)** ETSI tour of process	**(0630 – 0730)** ETSI tour of process	**(0630 – 0730)** ETSI tour of process	**(0630 – 0730)** Re-tour any process if needed
(0800 – 0900) Introduction/ overview meeting	**(0800 – 0830)** Summarize Process #1: Heating Plant	**(0800 – 0830)** Summarize Process #2 Laundry	**(0800 – 0830)** Summarize Process #3 Paint/Blast	**(0800 – 0830)** Summarize Process #4 Engine repair/overhaul
(0900 – 1200) Develop OLBs Base-wide OLBs: Electricity natural gas and water/waste water -Process specific OLBs: 1. Heating plant 2. Laundry 3. Paint/blast 4. Engine repair / overhaul	**(0830 – 1700)** ***Process #2:*** ***Laundry*** AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% “What Ifs” 3. Develop simplified Block Process Flow Diagram	**(0830 – 1700)** ***Process #3:*** ***Paint/Blast*** AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% “What Ifs” 3. Develop simplified Block Process Flow Diagram	**(0830 – 1700)** ***Process #4:*** ***Engine repair/overhaul*** AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% “What Ifs” 3. Develop simplified Block Process Flow Diagram	**(0830 – 1030)** Prepare for Debrief Session **(1030 – 1200)** Debrief Session
(1200 – 1300) Lunch	**(1200 – 1300) Lunch**	**(1200 – 1300) Lunch**	**(1200 – 1300) Lunch**	**1200 – Adjourn**
(1300 – 1700) Process #1: Heating Plant 1. Identify CCIs 2. Tour Heating plant 3. Brainstorm PEO solutions 4. Select and group solutions 5. Develop PEO economics	Process #2: Laundry PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select “top” PEO solutions 7. Develop PEO economics	Process #3: Paint/Blast PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select “top” PEO solutions 7. Develop PEO economics	Process #4: Engine repair/overhaul PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select “top” PEO solutions 7. Develop PEO economics	ETSI documentation work begins.
1700 – Adjourn	**1700** – Adjourn	**1700** – Adjourn	**1700** – Adjourn	

OLB: One-Line utility Balance POA: Process Optimization Assessment CCI: Critical Cost Issue PEO: Process Energy Optimization

Figure 2. Master audit schedule.

3 Fort Leonard Wood Energy Analysis

Costs

This Chapter summarize cost and usage for electricity, natural gas, liquid propane, and fuel oil. It also shows the detailed calculations that translate these amounts into corresponding values for steam.

Annual Electric Consumption and Costs

In 2002, Fort Leonard had an average electric load of 20,200 kW and used 176,800,000 kWh for a total cost of $7,032,000. This cost has two components. The first is the energy cost for kWh consumption. The cost for this was $4,232,000, or 60 percent of the total cost. The second component is a demand charge for the highest kW demand in any 30-minute period during the year. The charge for peak demand for 2002 was based on a 3-year average peak of 37,800 kW. The cost for this charge was $2,800,000, or 40 percent of the total cost. The demand charge is a relatively significant percentage of the total cost because Fort Leonard Wood has a relatively low load factor due to a high summer peak. The annual load factor equals the average kW demand over the year divided by the peak demand in any one 30-minute time period. Therefore, the annual load factor = 20,200 kW/37,800 kW = 0.53.

Annual Fuels Consumption and Cost

Table 5 lists, the amounts of natural gas, liquid propane, and No. 2 fuel oil Fort Leonard Wood installation used during 2002.

Table 5. Use of natural gas, liquid propane, and No. 2 fuel oil at Fort Leonard Wood, MO.

Fuel type	2002 Usage (MMBtu's)	2002 Annual Cost ($)
Natural Gas (NG)	663,600	$7,300,000
Liquid Propane (LP)	192,300	$1,500,000
No. 2 Fuel Oil (FO)	152,400	$800,000
Total	1,008,300	$9,600,000

Unit Cost Calculations and Cost Basis of Savings (CBoS)

Since specific energy conservation measures focus on some type of end use utility like compressed air, shaft power, lighting, etc. to support a process, the team needed a method to translate reduced consumption at the end use back to lower electricity usage or lower fuel consumption and the associated cost savings. As a result, the team was provided with translation formulas that convert incremental end use consumption back to the energy source and ultimately back to dollar cost. This is called the Cost Basis of Savings or (CBoS). Table 6 lists the cost values for an incremental unit of a utility and the underlying equation that derives this amount. The Post Energy Team (PET) may continue to use this table for future ECMs and since the formulas are shown, they can modify the CBoS based on changes in operating assumptions.

Links Between Electricity and Environmental Emissions

Electricity: Basis for 1,000 kWh (1 MWh)

Electric Generation Assumption for the Southeastern United States.

Table 6. Cost Basis of Savings (CBoS).

Utility or cost factor	Derivation and Cost
1. Electricity	\$0.0398/kWh including both energy and demand. Energy cost = \$0.025/kWh for energy Demand charge = \$6.18/kW-month \$349/kW-year (combined energy and demand) = 1 kW used for 8,760 hours/year \$74/kW-year (demand only)
2. Horsepower	1 hp x 0.746 kW/Hp x 8760hours/yr x \$0.0398/kWh = \$260/hp-yr
3. Natural Gas	\$11.00/MMBtu (includes fixed cost for pipeline at \$112k/month = \$1,344k/year)
4. Propane	\$0.70/gal 1,000,000Btu/90,000Btu/gal propane = 11.11gal/MMBtu x \$0.70/gal = \$7.80/MMBtu
5. #2 Fuel Oil	\$0.68/gal 1,000,000Btu/130,000Btu/gal#2F.O. x \$0.68/gal #2F.O. = \$5.25/MMBtu
6. Steam/HTHW (a) Laundry (LP) (b) Specker, 1021 (c) a + b w/ #2 FO	 \$7.80/MMBtu w/ 70% efficiency = \$10.40/klb \$11.00/MMBtu w/ 80% efficiency = \$13.20/klb \$5.25/MMBtu w/82% efficiency = \$7.30/klb
7. Water and Sewer	Water = \$1,068,800/year = 1,460,400kgal/yr @ \$0.73/kgal Sewer = \$272k/yr = 710,800kgal (REEP data) @ \$0.38/kgal

This work assumed that, in Missouri, most electric generation in the region is coal fired at an average heat rate of 11,000 Btu/kWh.

Emission Assumptions for the Southeastern United States

1,000 kWh (coal-fired) = 2,170 lb CO_2 or 1.085 tons

1,000 kWh (coal fired) = 4.5 lb NO_x

1,000 kWh (coal fired) = 24.5 lb SO_2

Patterns of Electricity Use

This section analyzes hourly electric load data over different intervals of time at Fort Leonard Wood. Fort Leonard Wood provided interval data for the period April 2002 to March 2003. Researchers examined this data, posed questions that will require further investigation, and drew some conclusions that may be helpful in guiding Fort Leonard Wood PET toward more productive energy management strategies.

Load Profiles and Load Duration Curves

Load profiles and load duration curves are tools that energy managers use to uncover usage trends and patterns, and opportunities for energy savings. The following discussion provides an analysis of Figures 3 to 9.

Typical Weekly Load Profiles by Season

These load profiles are 168 hour chronological graphs of load data that go from Monday to Sunday during different weather and/or business operating seasons. They typically vary because of the influences of weather and seasonal production cycles.

Figures 3 through 6 show the typical weekly load profiles by seasonal time of year for Fort Leonard Wood. Fort Leonard Wood is an Army training facility with hot, humid summer weather conditions. Therefore, there is a large degree of variation between summer and the other seasons. The seasonal population of the installation also is a contributing factor.

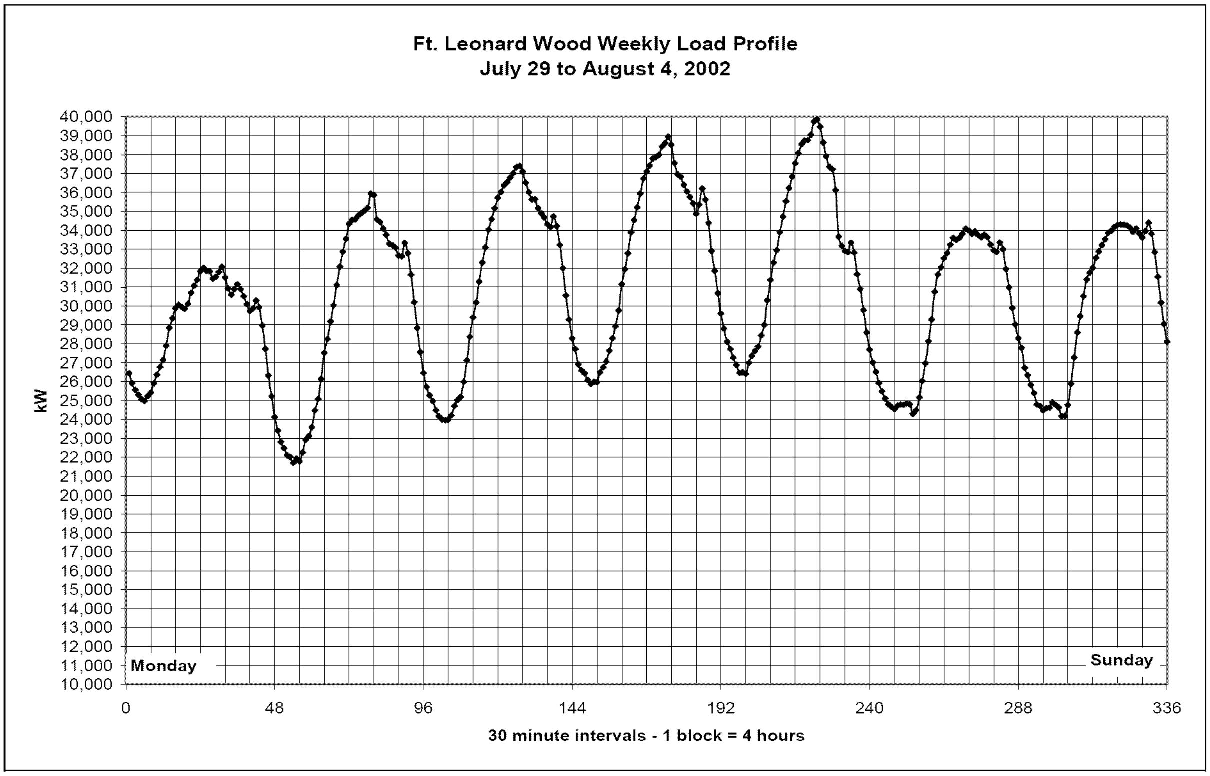


Figure 3. Weekly load profile: peak load in summer.

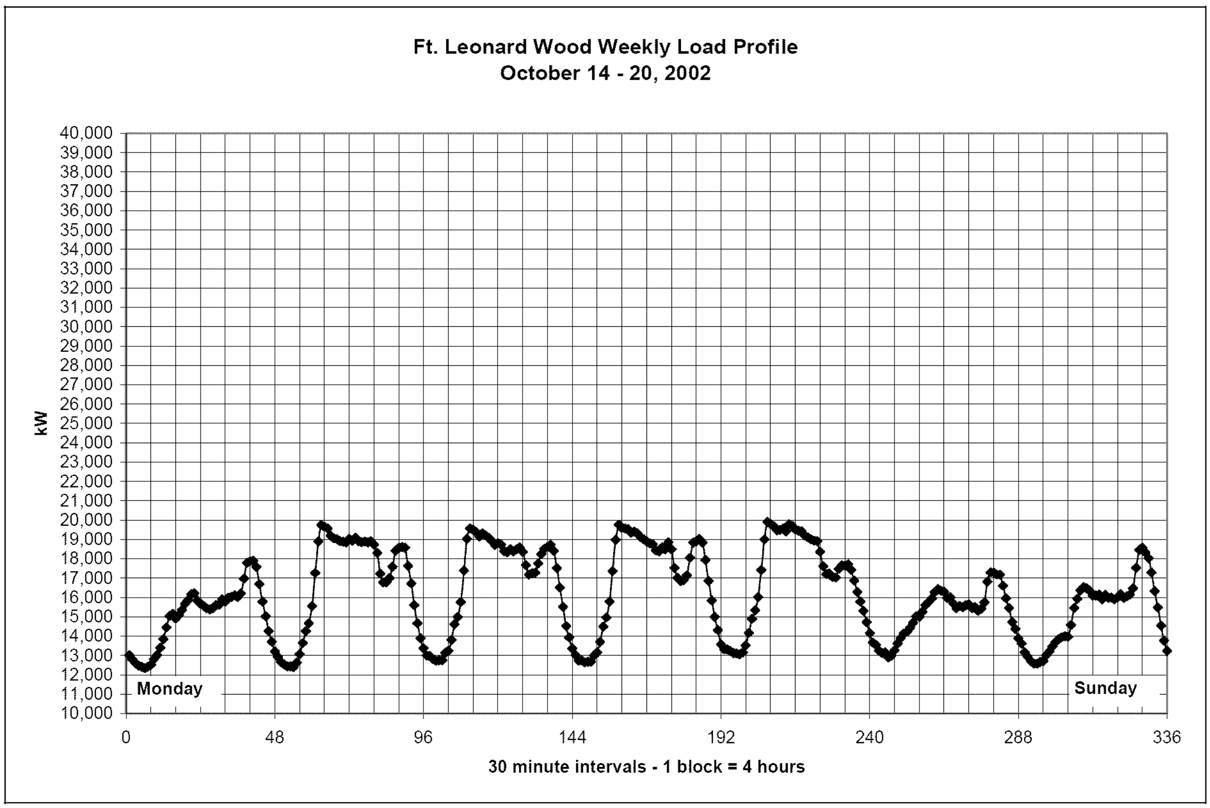


Figure 4. Weekly load profile: off-peak period in fall.

Figure 3 shows a weekly load profile for 29 July to 4 August 2002. This peak for the 12 months of data appeared during this week on Friday at 3:30 p.m. It was probably a very hot and humid day, with a resultant simultaneous heavy air-conditioning load. The graph reveals a distinct weekday pattern and a weekend peak that represents about an 85 to 90 percent of the weekday peak. This makes sense because the installation has such a large amount of family housing, barracks and retail business activity that is active every day of the week.

Figure 4 shows a weekly load profile for 14–20 October 2002. This profile shows a much lower peak electric load than in the summer. This confirms the notion that weather is a significant factor in electric demand.

Figure 5 shows a weekly load profile for 23–29 December 2002. This period is the lowest of the year. According to the energy team, the installation population should be at an annual low as well. The profile does not have a consistent daily shape and appears erratic. This is probably driven by inconsistent activity throughout the week.

Figure 6 shows a load profile for a 2-week period from 8–21 April 2002. The 2-week period reveals a transition period from one week with a peak demand of about 20,000 kW to the next week where the peak demand goes up to about 27,000 kW, an increase of 35 percent. This could have been either population or weather related. Perhaps there was an influx of troops and an increase in temperature at the same time.

Questions for PET

- What could be done in family housing and the barracks to control peak demand in the summer? (Figure 3)
- Is the base population about the same during the fall (Figure 4) or significantly lower than in the summertime?
- Is the base population is very low during Christmas break (Figure 5)? If so, could more electrical systems be turned off to lower total energy consumption even more during periods like this when the population is relatively low?
- What happened during April 2002 (Figure 6) that caused the load to increase so dramatically?

Annual Chronological Load Profiles

The annual chronological load profile is a graph of the electrical load levels shown sequentially over the 8,760 hrs of the year. This view shows variability in usage from hour to hour, day to day and month to month.

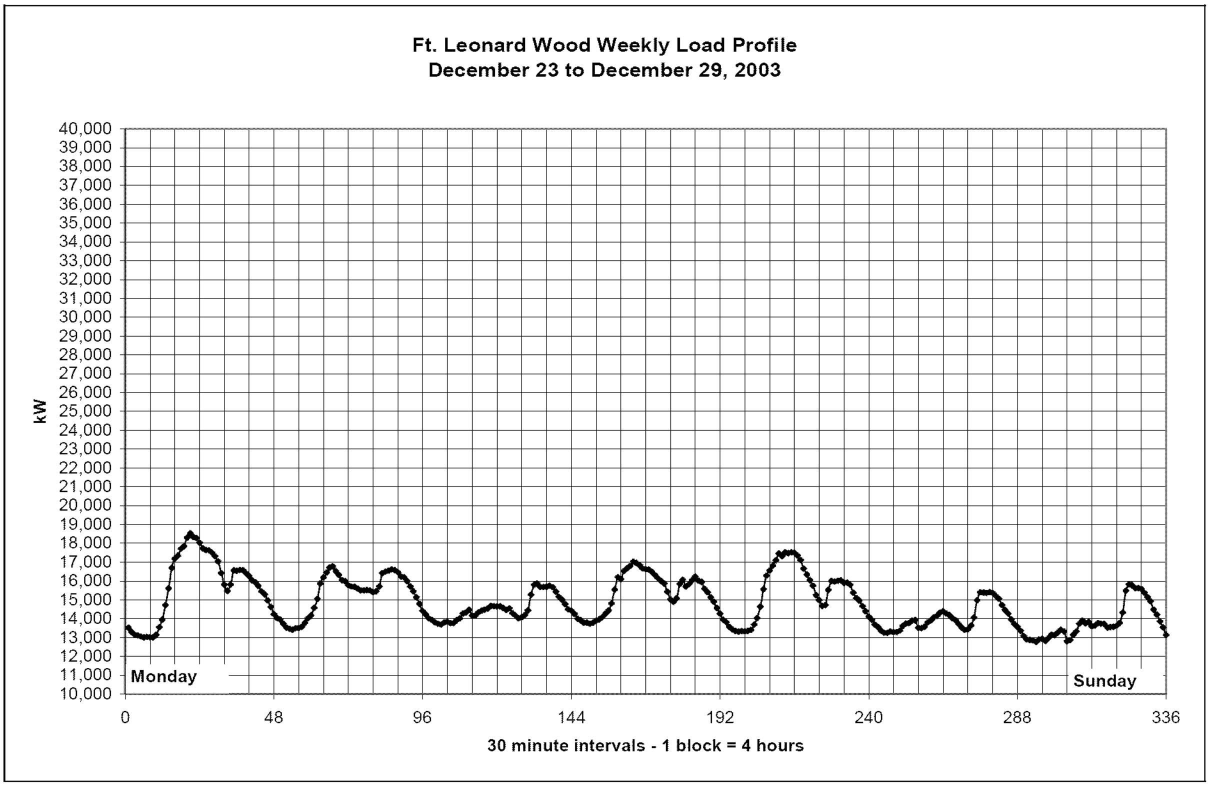


Figure 5. Weekly load profile: Christmas holiday break.

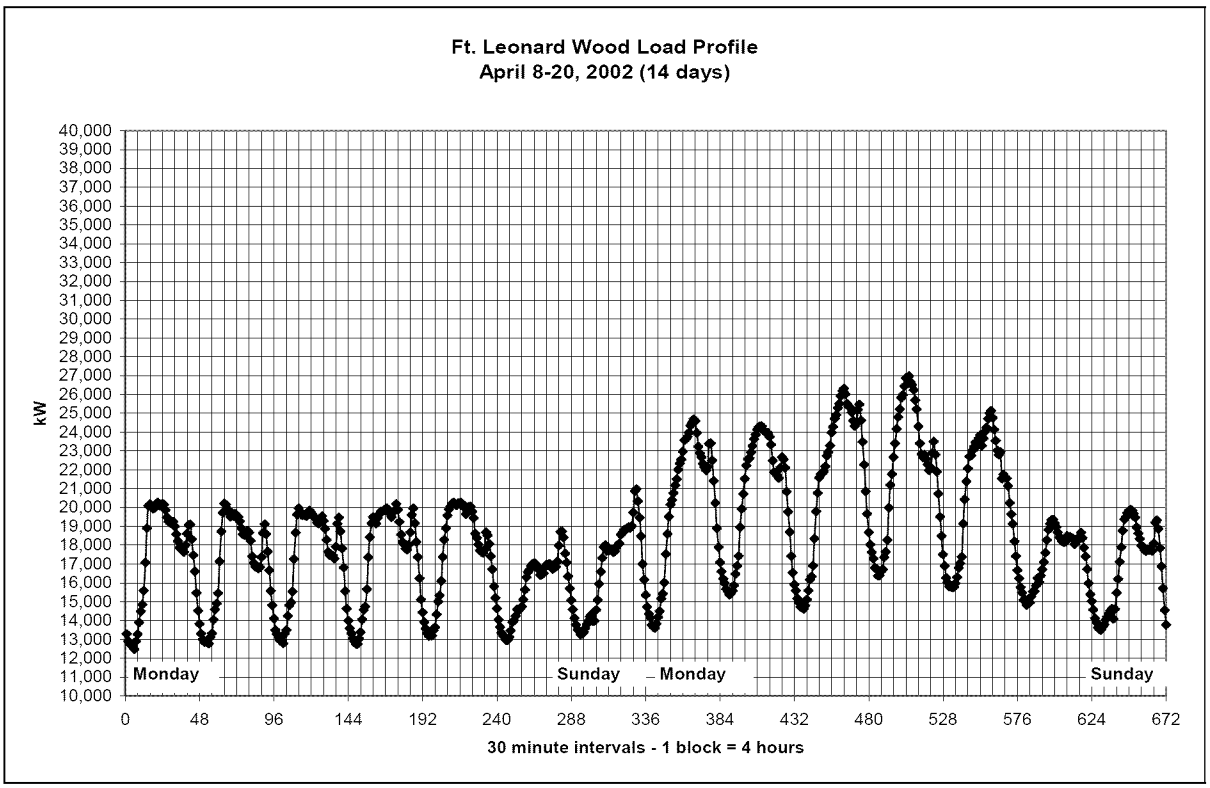


Figure 6. Load profile: 2-week transition period in spring.

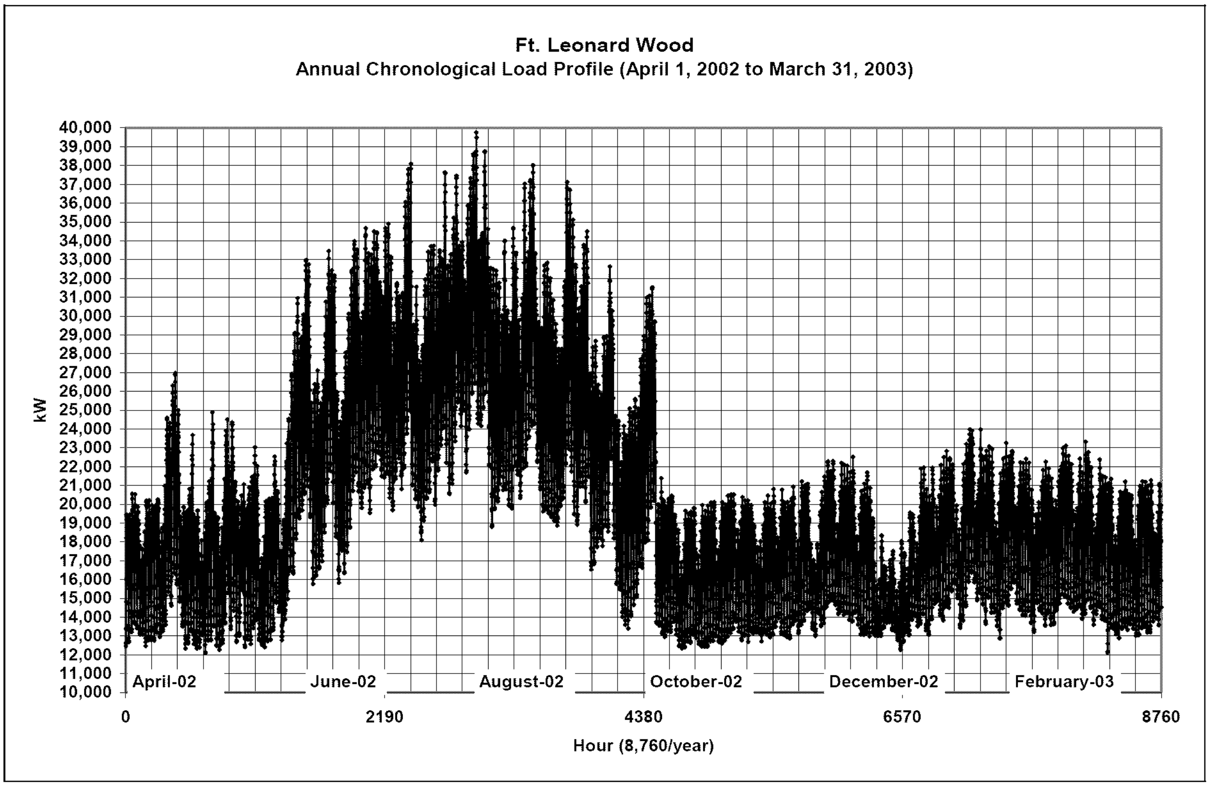


Figure 7. Annual chronological load profile.

Figure 7 shows the annual chronological load profile for Fort Leonard Wood. It reveals how the load varies from about (12,000 kW) during Christmas holiday to almost 40,000 kW during a hot summer afternoon in August.

Question for the PET

The night-time, weekend and holiday demand goes between 12,000 kW and 16,000 kW during non-summer months. Are all of these loads, particularly HVAC loads (motor loads) during the fall and spring justified? A reduction of 1,000 kW of load for nights and weekends (60 percent of the week) during spring and fall (50 percent of the year) is equal to about $65,700 ($0.025/kWh [energy only] x 8760 hrs/yr x 60 percent [weeknights and weekends] x 50 percent [spring and fall] x 1,000 kW).

Annual Load Duration Curve

The annual load duration curve is derived from re-ordering 8,760 hrs of load data recorded over a period of a year from the highest load observed to the lowest load observed. This curve provides unique insight into the levels of energy usage throughout a given period of time. The area under the curve represents the total

kWh usage during the year. It is especially useful in evaluating peak shaving opportunities.

Figure 8 shows the annual load duration curve for Fort Leonard Wood. The highest demand observed on a monthly basis is in August and July. There may be opportunities to shave about 2,000 kW from the peak over a very small number of hours using existing standby generators. Figure 9 shows the when and how many times load management would have been required to meet this goal of 2,000 kW during the summer of 2002. Due to their impacts on operations, base electric engineers do not believe that using existing standby generators for peak shaving to be realistic, since they all are for critical facilities and emergency operations. Thus no further consideration is undertaken.

Energy Sub-Metering for Plant Utilities

Even though the site-wide electrical hourly energy data is very helpful, it does not provide insight into the hourly energy usage by electrical system or end use. It is critical to obtain sub-metered data that gives this level of granularity. To effectively manage energy, it must be measured at a level that is controllable.

Fort Leonard Wood sub-meters by substation. While this is very helpful in getting down to a better level of detail, it still does not enable the PET to really understand areas where the load could be controlled more effectively. To develop and monitor effective ECMs, the PET needs to record sub-metered data on more points and to monitor the results from ECMs that are implemented (see ECM PW-05, p 34)

Conclusions

The load duration curve and load profile graphs create a clear picture of the usage patterns at Fort Leonard Wood. First, there is wide variation in usage patterns throughout the year. Since the electricity usage at Fort Leonard Wood is highly dependent on weather and installation population levels, the post has a relatively low load factor (average load/peak load). This means that the PET should examine opportunities to shave peak demand.

There are also significant opportunities to save kWh. The greatest area of savings potential is during the weeknights and weekends. There may also be savings potential during every hour to turn off unnecessary equipment, however, without sub-meter data, it is difficult to identify these specific opportunities.

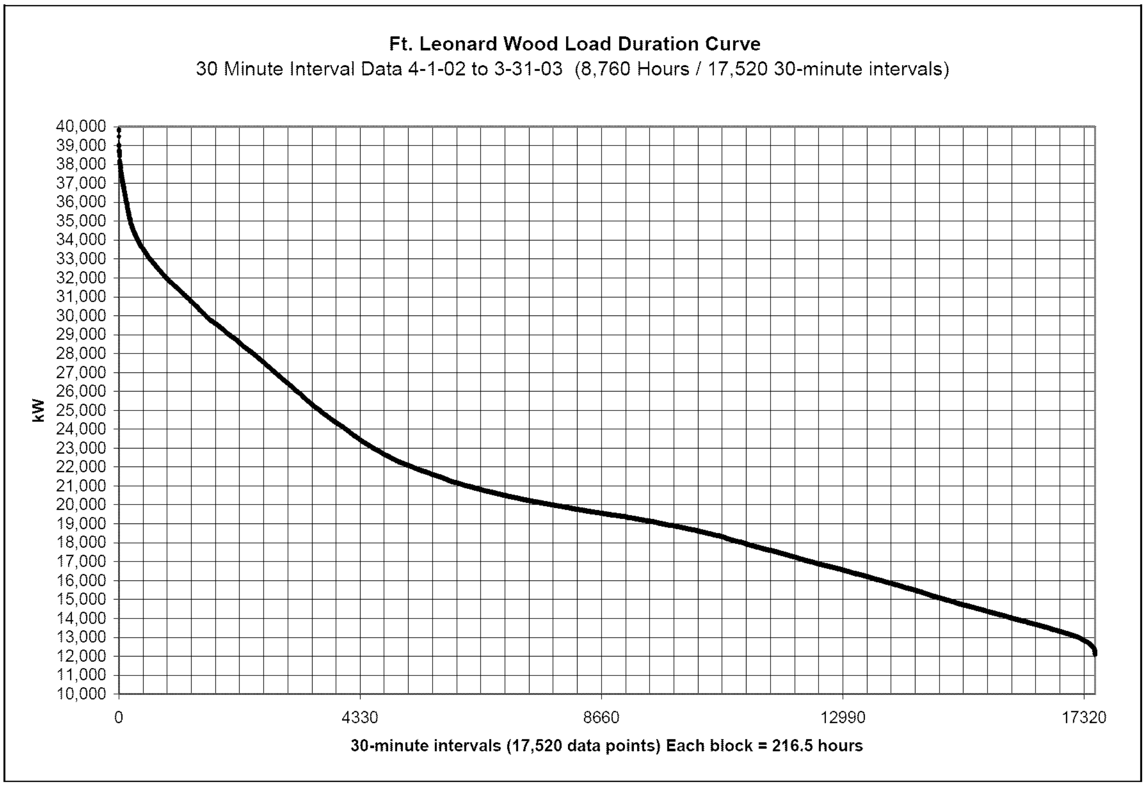


Figure 8. Annual load duration curve.

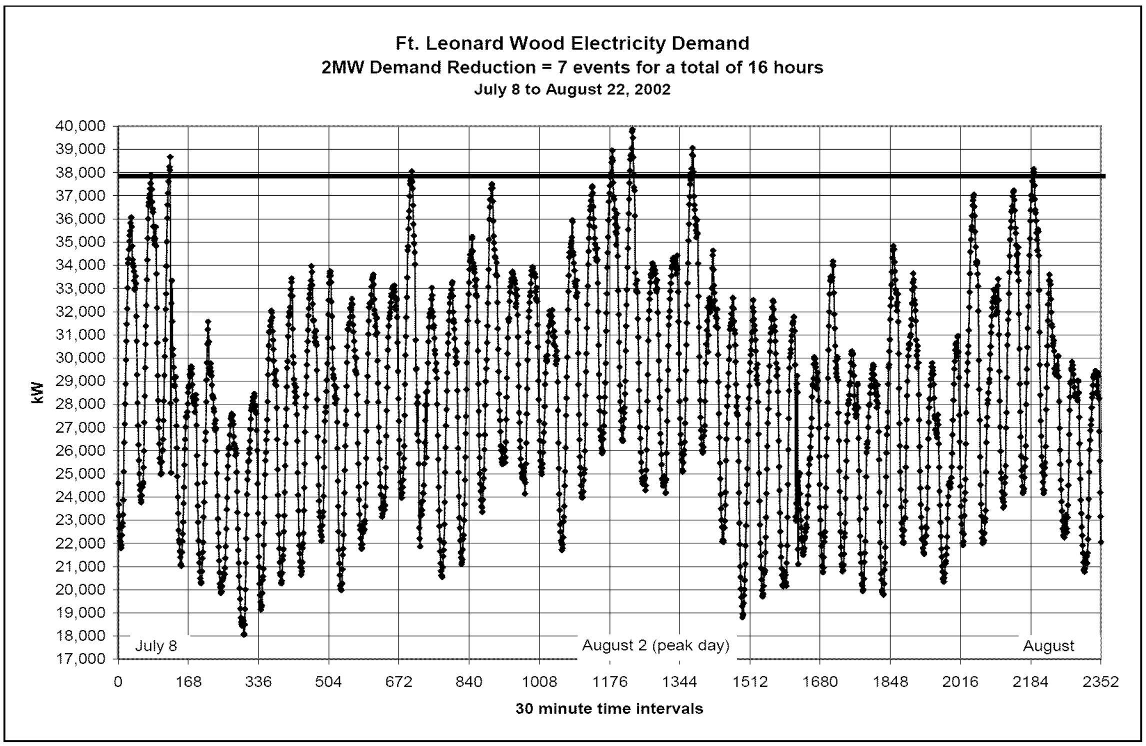


Figure 9. 2,000 kW peak reduction opportunity in 2002.

One Line Balances (OLBs)

This section provides unique representations of the utility systems called "One Line Balances" (OLBs). The OLB is a diagram that accounts for all of a plant utility flow and annual cost from the source to the major end users. OLBs are meant to be simple and approximate, not precise or necessarily 100 percent complete. The primary purpose of an OLB is to obtain a total energy picture of the installation that will:

1. Stimulate the POA Team to identify more and better ECMs and POMs
2. Provide a basis from which the recommended measures can be technically and economically quantified

The OLB for Fort Leonard Wood electricity (Figure 10) shows the installation's 20,200 kW (annual average load), totaling 176,800 MWh/yr at an annual cost of $7,032,000 and the consumption and cost to all major plant energy systems and departments.

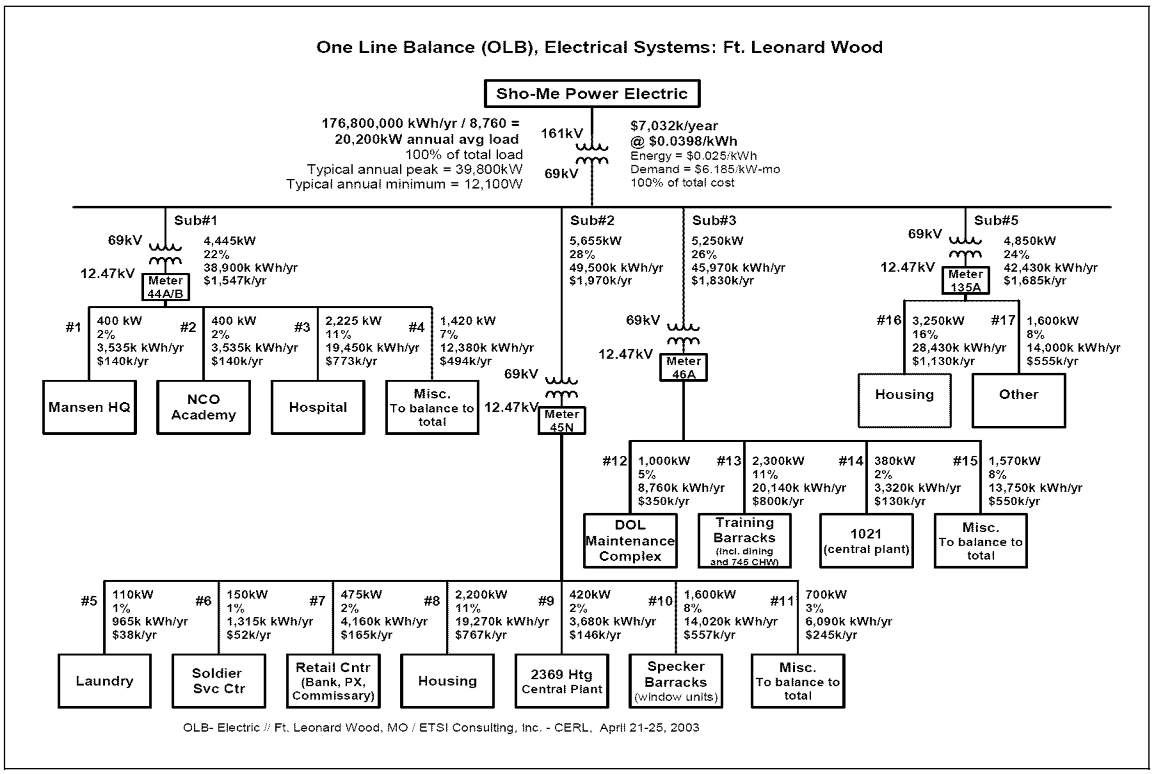


Figure 10. OLB for electrical supply, distribution, and major users.

The OLB for Electricity estimates the approximate kW flows through the post distribution systems by voltage levels to all major users.

The OLB for Fort Leonard Wood Fuel (Figure 11) shows the post's 1,008,300 MMBtu per year at an annual cost of $9,600,000 and the consumption and cost to all major plant energy systems and departments.

OLBs provide many benefits to the Audit and analysis. Six of the benefits of OLBs are that they:

1. Account for energy at the point of use and create an immediate overall understanding of how energy is being used
2. Help the team prioritize their efforts and save time by directing their efforts to the energy systems that consume the most dollars (the greatest financial opportunities)
3. Provide a structured method to quickly stimulate the team to consider ECMs throughout the plant energy system
4. Assist in calculating the savings values of ECMs and groups of ECMs
5. Provide a realistic basis to allocate energy costs to plant areas and business units even without sub-meters
6. Provide a powerful communication tool to explain energy use and costs to plant management and add credibility to the PET efforts.

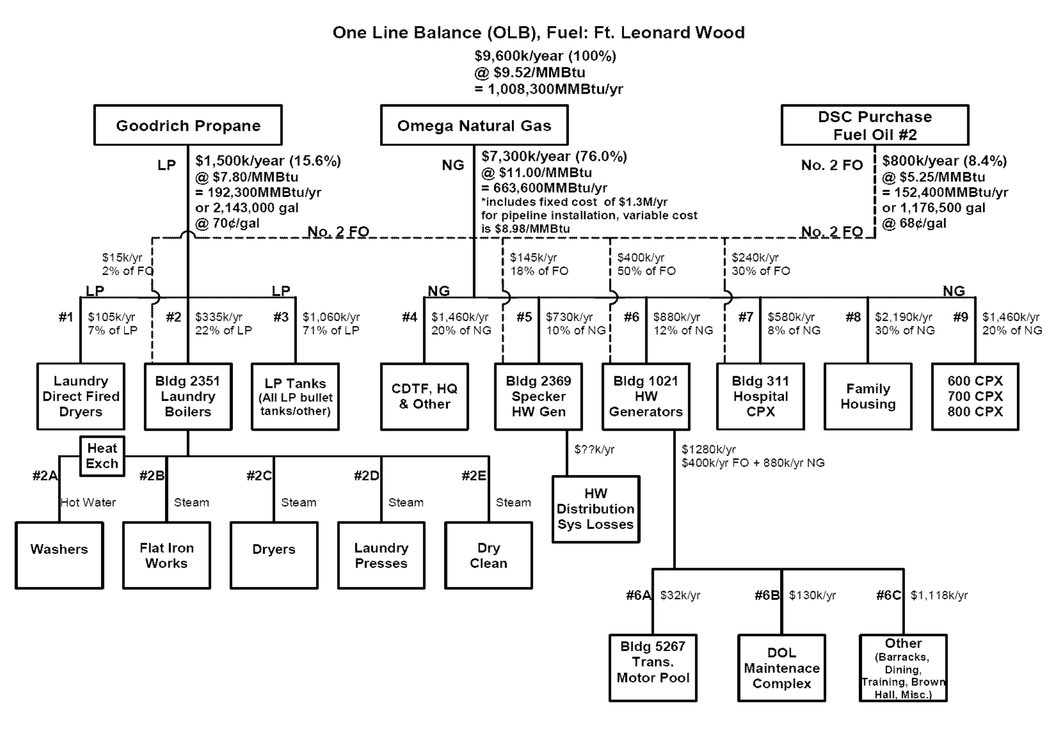


Figure 11. OLB for fuel supply, distribution, and major users.

During the on-site period from 19-23 April, the POA team examined three primary process areas:
1. Heating plants
2. Laundry
3. DOL Maintenance Complex with special emphasis on the wheel shop, heavy shop, and paint/blast.

The team used the approach outlined here for process optimization to analyze, both technically and financially, each process and to uncover critical cost issues specific to each area. The team then collectively identified solutions to the most costly problems. This section of the report shows:
- summary results in table format
- critical cost issues that were identified
- the manufacturing cost structure (where appropriate) and resulting value of process improvements related to improving turnaround time (TAT), labor productivity, decreasing scrap and waste and using energy more efficiently
- detailed results in one- to two-page format.

The summary matrices for each process area show the following information by energy system:
- *ECM Number and Title*: A unique number and title that may be referred to in the text of the document
- *Annual Savings*: The savings calculation formula derived from the Data Used for Economics. For projects paid for with expense money, this result is shown as net of "expense" dollars that are required to implement.
- *Installed Cost*: Cost derived from the Data Used for Economics and the cost calculation for any "capitalized" dollars that must be expended to fund the project.
- *Simple Payback*: The simple payback is calculated by dividing the capital cost by the "net savings," expressed in years. For projects that do not require capital investment, the payback is immediate.

The one-page discussion of each ECM includes:
- *ECM Number and Title*: A unique number and title that may be referred to in the text of the document
- *Background*: Information about the target location in the plant and a statement of fact about the current situation
- *Descriptive Scope*: The specific action that will be completed to implement the ECM. It answers the questions what to do, how to do it, where to do it, and when to do it. For example, "install (how?) VFD on 10 hp compressor fan (what?) in heating plant No. 2351 Care (where?)"

- *Data Used for Economics*. This provides any relevant data that may be used as an input assumption into the calculation of costs and savings for the ECM. It generally includes operating and specification data related to the equipment that will be modified, reduction data that quantifies the use and energy reduction of the equipment, and cost data related to material, labor and other expenses associated with making the recommended changes
- *Savings Calculation*: The savings calculation formula that is derived from the Data Used for Economics. For projects paid for with expense money, this result is shown as net of "expense" dollars that are required to implement.
- *Cost Estimate Calculation*: Cost derived from the Data Used for Economics and the cost calculation for any "capitalized" dollars that must be expended to fund the project
- *ECM Summary*: A table that shows the financial savings and simple payback and the energy and environmental savings. The simple payback is calculated by dividing the capital cost by the "net savings" and expressed in years. For projects that require no capital investment, the payback is immediate.

4 Fort Leonard Wood Installation-Wide Results

This Chapter is dedicated to ECMs that came out of the POA that are not necessarily specific to any one area of the installation.

Object Statement: Identify ECM solutions that will optimize energy cost post-wide (higher efficiency, lower consumption) at equal or better TAT, quality of life, safety or morale (Table 7).

Table 7. Post-Wide (PW) ECMs.

ECM	Energy Conservation Measure (ECM) Descriptive scope: what, where, why	Category (SD, LU, etc.)	Net Savings ($k/yr)	Capital Cost ($k)	Simple Payback (yrs)
PW-01	Optimize use of lowest cost fuel, post-wide	SD	$1,019.00	$0.00	Immed.
PW-02	Add shut-off controls to all air compressors that are left on when not needed.	CP	$27.40	$100.00	3.7
PW-03	Replace standard V-belts with COG type V-belts to save 2% of motor load	LU	$10.00	$0.00	Immed.
PW-04	Insulate and repair leaks on all justifiable steam and HW systems, post-wide underground distribution systems	PET	$215.00	$430.00 (assume 2 yr pb)	2.0
PW-05	Develop long term metering plan to save 2% of electricity cost	CP	$140.00	$140.60	1.0
	Total		$1,596.40	$720.60	0.45

Abbreviations: ECM area and categories:
PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost); LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical; PET = follow up by the PET

Critical Cost Issues – Post Wide

Task: Identify CCIs that apply to Post-wide problems that, if solved, will save $$ and improve the end user operations; CCIs = problems or opportunities that waste a significant amount of $$ (Table 8).

Table 8. Critical cost issues—post wide.

CCI	Description (what and where)	Cost calculation	Estimated cost of problem
1.	Natural Gas is very expensive at $11.00/MMBtu.	No. 2 F.O. is 50%@ $5.25/MMBtu. Potential savings = $750 k/yr	$750.0 k/yr
2	No EMCS to control peak demand (now 39MW).	Worth $74.0 k-MW. Reducing peak demand by 10% = $300 k/yr	$300 k/yr

ECM PW-01

Facility: Fort Leonard Wood

Area: Four Heating plants, Post-Wide

Description: Optimize the use of the lowest cost boiler fuel.

Background

Fuel prices per MMBtu for the four heating plants vary widely from $11.00 for natural gas (NG) (including $2.03/MMBtu equivalent for pipeline) to $7.80 for propane (LP) to $5.25/MMBtu for No. 2 fuel oil (FO). Past practice has been to burn LP and NG at all times, regardless of fuel price, unless there are fuel supply interruptions, in which case No. 2 FO is used as a backup. This occurred approximately 15 percent of the time last year. The most economical fuel of choice is to use No. 2 FO when ever it is cheaper than LP or NG. An argument could be made that light fuel oil is somewhat less environmentally friendly than LP or NG. However, No. 2 FO has a higher (better) ratio of LHV to HHV (0.93) than LP (0.92) or NG (0.90) resulting in 1 to 3 percent less fuel consumption per pound of steam. Otherwise, No. 2 FO burns cleanly with little or no particulate emission and no significant operating or maintenance problems (see Status/Recommendations below).

Descriptive Scope

Use No. 2 FO in all four boiler systems whenever the price is significantly advantageous. The purpose of this ECM analysis is to clearly show the economic significance of the current practice of minimizing the use of the lowest cost fuel.

Data Used for Economics

Actual fuel cost for 2002 were (see OLB Fuel [Figure 11] and CBoS [Table 6]):

- NG: $7,300K/yr @ $11.00/MMBtu including $112K/month or $1,344K/yr fixed cost to Omega Natural Gas for the pipeline installation.
- LP: $1,500K/yr @ $7.80/MMBtu
- No. 2 FO: $800K/yr @ $5.25/MMBtu
- NG (variable only, excluding fixed pipeline cost): ($7,300K/yr - $1,344K/yr)/663,600MMBtu/yr = $8.98/MMBtu

Savings Calculation

Annual $ savings =

($335K/yr/$7.80/MMBtu) x ($7.80 - $5.25/MMBtu) = $109K

([$730K + $880K + $580K]/$8.98) x ($8.98 - $5.25/MMBtu) = $910K/yr

Total savings = $109K/yr + $910K/yr = $1,019K/yr

Cost Estimate Calculations

Total Cost =

No capital or expense costs are required (Table 9). The fixed cost for the NG pipeline of $1,344K/yr will still be paid. The savings for the NG that is displaced by FO in the four central heating plants is based on the variable cost of NG ($8.98 vs. $11.00/MMBtu) as shown in item 2 of the savings calculation above.

Table 9. ECM PW-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$1,019.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam Dunk

Status/Recommendations for Further Work

The PET should determine what Fort Leonard Wood's decision will be on this recommendation. There may be concerns about an environmental issue of replacing LP and NG with No. 2 FO. Technically and practically this would not normally be considered an issue. If there are environmental concerns ("dust" from No. 2 FO was mentioned), it likely contributes less than 1 percent of the volume of road dust created by from wheeled and tracked vehicles. A possible compromise is to take a portion of the $1,019K/yr savings and put it to community benefit and realize good PR by upgrading the old burners to new low NOx design. New, high efficiency, low NOx burners would also eliminate the need for using compressed air to atomize the No. 2 FO and would further reduce particulates and improve combustion efficiency.

Updated information (as of 25 June 2003)

The PET is aggressively negotiating more economical pricing from the natural gas contractor to get parity with propane. The team also found out that, if they get an interruptible rate, the fixed charge of $1,344K/yr could be eliminated.

ECM PW-02

Facility: Fort Leonard Wood
Area: Post-wide air compressors
Description: Shut-off controls to all air compressors that are often left on when not needed.

Background

A recent compressed air study by the Federal Energy Management Program (FEMP) at Fort Carson (May 2003), estimated that many of the 1300 small (5–100 hp) air compressors were continuously left on, for the soul purpose of supplying leaks all night long. Fort Leonard Wood surely has far fewer compressors and is doing a far better job of turning units off when not needed. However, it is quite possible that some of the compressors are overlooked or ignored and left on to maintain 100 psi in the system.

Descriptive Scope

Install automatic shut-off controls on those air compressors that might be often overlooked or ignored and left on during the nights and weekends.

Data Used for Economics: Assumptions

- 500 air compressors between 5 and 100 hp post-wide, averaging 10 hp each
- 20% are candidates for auto shut-off controls (100 units)
- The avoided run time is 10 hr/day x 5 day work week plus 20 hrs x 2 days/weekend = 90 hrs/wk
- The operating load for 90 hr/wk is the average 10 hp unit x 3 CFM/hp = 30 CFM
- The cost of a 1000 CFM at 4¢/kWh = $0.13/1000 CF
- The duty cycle run time to supply leaks is 25%
- Install cost for auto start/stop is $1,000/unit.

Savings Calculation

500 units x 20% (which need shut-off) x 30 CFM/unit x (90 hr/wk x 60 min/hr x 52 wks a year) x 25% duty cycle x $0.13/KCF = $27,400/yr.

Cost Estimate Calculations

Installed cost for 100 auto start/stop controls is 100 units x 1000/unit is $100,000. Simple payback = 3.7 years.

Table 10 lists the economic and benefits from implementing ECM PW-04.

Table 10. ECM PW-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$27.4K
Capital Cost ($)	$100.0K
Simple Payback (years)	3.7 years
Comments	Capital project

Status/Recommendations for Further Work

Identify the “assumed” 100 air compressors that are left on in auto start/stop operating mode to holds system pressure set point. Install timers to auto start and stop operating hours for the required period on use.

ECM PW-03

Facility: Fort Leonard Wood
Area: Post-wide V-belt driven equipment
Description: Replace standard V-belts with the high efficiency COG V-belts.

Background

A small portion of the Post’s electrical load is motor driven ventilation fans, air compressors, etc., that use V-belts in use are standard (lowest 1^{st} cost) V belts. An improved V-belt design is called COG belts which reduce belt transmission losses by 50 percent (from 3 to 1.5 percent) and last twice as long (2 yrs as opposed to 1 yr) as the standard belt. The COG V-belt uses the same sheaves as the standard V-belts.

Descriptive Scope

Replace all standard V-belts with COG type V-belts on motor fan drives, air compressors, etc. to reduce energy consumption, maintenance, and overall initial purchase cost.

Data Used for Economics

- Average Post Electrical load is 20,200 kW costing $7,032K year
- V-belt driven equipment is 5% of the load and 90% of these are standard V-belts.
- The duty cycle for this equipment is 50% of the year.
- The net energy savings are 3.0% losses for standard belts minus 1.5% for COG V-belt = 1.5%
- 50% lower maintenance costs at $30/hr for the average belt
- A total of 440 V-belts are in use, and maintenance labor per belt change is $30/belt = $13,200/yr

Savings Calculation

Energy Savings =

7,032K/yr Post-Wide electric x 5% V-belts x 90% standard belts
x 50% duty cycle x 1.5% savings = $2,400/yr.

Maintenance Savings =

50% fewer belt changes on 1300 hp of belt x 1 belt/3 hp = 220 changes/yr.
220 changes/yr x $30 /belt = $6,600/yr.

Cost Estimate Calculations

No capital costs and, even though the COG V-belt costs 20 percent more than the standard V-belt, the cost is 40 percent less because it lasts twice as long (2 yrs vs. 1 yr, cf. Table 11).

Table 11. ECM PW-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$10.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay up

Status/Recommendations for Further Work

Return all standard V-belts in stock to supplier and insist on refund and replace all stock equipment with the equivalent COG V-belt.

ECM PW-04

Facility: Fort Leonard Wood
Area: Post-wide central heating distribution systems
Description: Insulate and repair underground leaks in the steam and hot water systems where justified

Background

The 40+ year old steam and hot water (HW) distribution systems from the four central plants are very large, representing morn than 10 miles of high temperature (typically 340 to 360 °F), poorly insulated, leaky pipe (75 percent below ground) and aboveground pipe, valves, and fittings. This issue is an on-going maintenance problem. A portion of the system has been decentralized (see OLB, complexes 600,700,800). However, approximately 25 percent of the heating loads remain on the underground central systems supplied by heating plants in buildings No. 2369 (Specker Complex), and No. 1021 (motor pools and maintenance complex). This represents more than $2 million/yr of the Post's annual fuel bill. The purpose of this broadly stated ECM is to provide an overall analysis of the economic picture of the Post-wide problem as a preliminary basis for how to best improve the system.

Descriptive Scope

Identify, quantify, and repair (where practical), all underground leaks in the steam and hot water systems. The economics of specific system losses in dollars/yr provide a rational basis to determine the economics to repair, replace, or abandon and decentralize.

Data Used for Economics

- Total fuel costs for steam and HW from building No. 2369 and No. 1021 centralized systems are $2,160K/yr.
- The system losses from a very well insulated, tight steam/HW central, underground system are 3 to 5 percent of the annual fuel bill. This would be only $85K/yr of $2,160K/yr.

- The fixed losses from large, underground central systems similar to Fort Leonard Wood range from 15 to 30 percent (reference Pine Bluff Arsenal, Watervliet Arsenal, NADEP San Diego, El Lilly Greenville, IN complex, Abbott Labs in North Chicago Complex, and others).
- The exact annual cost for the fixed system losses (poor insulation, leaks, etc.) are not known, but are estimated to be as much as 20 percent of $2,160K/yr, or $430K/yr and possibly more.

Savings Calculation

The challenge with this issue is what to fix, when to fix it, and when to replace it with a decentralized system. An annual fix and repair budget of $215K/yr would still keep the problem 50 percent ahead of estimated losses if in fact losses held to 215K/yr. Unfortunately, the cost of repair for the old system grows at 20 percent/yr, which will soon call for management decisions.

Cost Estimate Calculations

The annual repair costs of the Post's central HW systems over the last 10 years was unknown. If an accurate cost tracking account were available, the trend should show the current and future economic direction. This report assumes that the savings can be accomplished with a 2-year payback or less (Table 12).

Table 12. ECM PW-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$215.0K
Capital Cost ($)	$430.0K
Simple Payback (years)	2.0
Comments	Defer to PET

Status/Recommendations for Further Work

Commission a system-wide study that defines the past, present, and future economics of the central HW systems. This study does not need to be in highly detailed and costly, but rather sharply focused to define the most practical and economical solution to an efficient, reliable, and environmentally acceptable thermal supply that fully meets the sites objectives and mission.

ECM PW-05

Facility: Fort Leonard Wood.
Area: Post-wide
Description: Long term metering plan.

Background

Energy sub metering is a very valuable tool for improving the management of energy and improving efficiency.

Descriptive Scope

There are seven basic reasons to sub meter energy:

1. Verify accuracy of utility bills
2. Allocate energy costs to specific departments, shops, or processes
3. Assign personal accountability for energy uses
4. Determine equipment efficiency
5. Audit "before-and-after" energy usage for projects intended to improve efficiency
6. Identifies performance problems in processes and equipment
7. Discover opportunities for potential energy efficiency improvements (useful for planning future projects).

Data Used for Economics

- The 2M rule states "If you can't measure it, you can't manage it." By themselves, meters do not save money. They only cost money to purchase and install. The key to maximize energy savings is to combine the meters with accurate recordkeeping and to then act on the logged energy consumption
- Experience has shown that a well engineered and thought out metering system will result in annual savings or 2 to 5 percent of the energy cost when the appropriate action is taken based on the logged energy consumption.
- Actual quantity and specific location of electrical meter to be determined by the Fort Leonard Wood PET, with the assistance of outside engineering resources, as appropriate.
- Electrical meters @ $2,000 each installed (SQD Power Logic Units).

Savings Calculation

Annual $ savings = $7,032,000 x 2% savings from sub-metering =
$140,640 saved/yr in electricity

Cost Estimate Calculations

Total Cost = 70 meters x $2,000/electric meter = $140,000 cost

Table 13 lists the economic and benefits from implementing ECM PW-07.

Table 13. ECM PW-07 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$140.6K
Capital Cost ($)	$140.0K
Simple Payback (years)	1.0
Comments	Capital Project

Status/Recommendations for Further Work

Evaluate specific locations to sub-meter electricity.

5 Fort Leonard Wood Heating Plant Results

This Chapter shows results from ECMs identified in heat plants No. 1021, 2351, and 2369 (Table 14).

Object Statement: Identify ECM solutions that will optimize energy cost (higher efficiency and/or lower consumption) at equal or better output, quality of life, safety or morale.

Table 14. Heating system ECMs summary.

ECM	Energy Conservation Measure (ECM) Descriptive scope: what, where, why	Category (SD, LU, etc.)	Net Savings ($k/yr)	Capital Cost ($k)	Simple Payback (yrs)
HP-01	Install VFD on 10 hp combustion air fan and connect to continuous O_2 measurement in Heating Plant No. 2351 (laundry)	CP	$13.2	$33.0	2.5
HP-02	Insulate all bare and poorly insulated above-ground steam and HW lines	CP	$43.2	$33.8	2.5
HP-03	Install “in-stack” economizer to heat boiler feed water for Heating Plant No. 2351	CP	$13.4	$34.0	2.5
HP-04	Optimize 100 psi steam to meet warm weather HP No. 2351 requirements	SD	$1.0	$0.0	Immed.
HP-05	Optimize HW temperature at significantly lower levels and control off of HW return temperature for HP No. 2369	SD	$52.0	$0.0	Immed.
HP-06	Adjust barracks window opening to meet ventilation requirements and install ceiling fans	CP	$280.0	$120.0	0.4
HP-07	Optimize HW temperature at significantly lower levels and control off of HW return temperature for HP No. 1021	SD	$48.1	$0.0	Immed.
HP-08	Install VFD on 20 hp combustion air fan in HP No. 2369	CP	$45.1	$70.0	1.6
HP-09	Install VFD on 60 hp HW recirculation pumps in HP No. 2369	CP	$20.4	$24.0	1.2
HP-10	Install VFD on 30 hp combustion air fan in HP No. 1021	CP	$39.0	$37.5	1.0
HP-11	Install VFD on 75 hp HW recirculation pump in HP No. 1021	CP	$11.0	$15.0	1.4
	Total		$566.4	$367.3	0.6

Abbreviations: ECM area and categories:
PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost);
LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical;
PET = follow up by the PET

Critical Cost Issues – Heating Plants

Process No. 1: Heating Plants and Fueled-fired Systems

Task: Identify CCIs for heating plants, fuel and air-conditioning systems that if solved will save $$ and improve the end user operations (CCIs = problems or opportunities that waste a significant amount of $$; see Table 15).

Table 15. Critical cost issues—heating plants.

CCI	Description (what and where)	Cost calculation	Estimated cost of problem
1.	Inadequate ventilation in training barracks complex (600, 700, 800) (30) [10 with AC, 20 without AC] results in practice of opening windows causing excess heat loss and service calls	wastes 30% of $1,460,000/yr of new pulse HW heaters (approx $438,000/yr)	$440.0K/yr
2.	Same as No. 1 but on AC systems	approx $220,000/yr of CHW air-conditioning	$220.0K/yr
3.	In 1000 area there are leaks in the high temperature hot water distribution system	HW leaks for CCI 3. Q = m x CP x ΔT lb/hr 1 (360-60) = 1.0 x 300 $/yr = 4000 gal/day x 8.33 lb/gal/24 hr/day x 1.00 lb/°F x 300 = 420,000 Btu/hr x 4,400 = 2,150Mbtu/yr x $11.00/mmbtu = $24,100/yr	$24.1K/yr
4.	Old, high maintenance pneumatic controls in 600, 700, 800, 1000 areas are expensive to maintain	1 man year x $40.0K/man-year + $10.0K = $50.0K. $50.0K maintenance operating cost of air compressor/dryer. Cost $10K/building to replace with DDCx 60 buildings = $600.0K	$150.0K/yr
5.	Design problem with steam boiler capacity in mess halls	9 mess halls. This one is in the process of being fixed	$80.0K/yr
6.	Laundry boiler house (building 2351) wastes 1000 lb/hr of flash steam off condensate return vent (3+ meter plume of live steam)	$10/klb x 4000 hr/yr = $40,000/yr. Why? Steam traps blowing through	$40.0K/yr
7.	No economizer on boilers in building 2351	$20.0K	
8.	No VFD on 30 hp combustion air fan, yet IGVs are only 10% open.	2% efficiency gain ($500K x 2% = $10K) + $2.5K energy savings (30 hp x 0.746 x 90% loaded x 80% savings	

CCI	Description (what and where)	Cost calculation	Estimated cost of problem
9.	No insulation on 50 ft of 10-in. steam header inside 2351 heating plant or an equal amount of associated 2-6-in. uninsulated piping		
10.	No continuous O_2 monitoring with auto trim on fuel-to-air ratio	O_2 monitoring will control combustion air flow rate	
11.	No heat recovery on continuous blowdown		
12.	Large steam load swing when filling washing machines and starting dryers		
13.	Ditto No. 12 when starting direct-fired dryers		
14.	Largest year-round load on building 1021 heating plant is very high heat loss from leaky, poorly insulated high-temperature HW distribution system (10,000 ft of 2 to 10-in. underground lines)	This is "in progress"	
15.	Do not need 100 psi steam to laundry for 8 months/yr because of low flow condition		
16.	Do not need 365 °F HW where 335 °F HW is OK.		
17.	Do not need full flow from 60 hp circ. Pump during summer	On – 8 hr/day Jun-Sep. Off – 16 hr/day Jun-Sep. 60 hp x 0.746 kW/hp x 90% loaded x (1-0.5)3 x 2000 hr/yr x $0.0398/kWh	$10.0K
18.	Bldg 311 (hospital) has 6 Fulton, 100 hp boilers that can not be properly controlled for excess O_2 (70% efficient vs. 85% efficient) because of manifolding 3 stacks x 2 into 2 roof penetrations.	55 mil cf/yr x 1000Btu/cf x $11.00/MMBtu x ([85 to 70%]/70%) x 15% = $19,500	$20.0K/yr

ECM HP-01

Facility: Fort Leonard Wood

Area: Bldg No. 2351 Heating Plant [HP] Laundry)

Description: Install VFD on the designated "load-following" lead steam boiler combustion air fan and install continuous stack O2 measurement with automatic trim of fuel-to-air ratio control to VFD. Use the VFD equipped boiler as the lead unit and use the second boiler only when necessary during coldest winter heating period.

Background

Building No. 2351 HP provides 100 psig steam and 160 to 180 °F HW to the GOCO laundry (Penn Enterprises). The boilers (3 units, 1967) consume $335K/yr of LP and $15K/yr of No. 2 FO. The thermal load profile during the week varies widely based on the laundry operating hours (typically 5.5 days/wk x 10 hrs/day x 52 wks/yr) as required by the level of soldier occupancy. There has been a 15+ year discussion about moving the laundry operations off post, but practical issues (TAT, etc.) and economics keep the facility on post.

Descriptive Scope

Install variable frequency drives on the primary lead boiler combustion air fan to provide capability to efficiently follow the wide swing in daily steam loads from zero to 30,000 lb/hr. The VFD will significantly reduce fan motor load throughout the wide daily load variations (typically 20 to 80 percent, average 50 ± 30 percent)

Data Used for Economics

- Boiler load average 13 klb/hr for 2,900 hrs/yr.
- Two (2) boilers are currently running during laundry operating hours consuming $350K/yr fuel. Otherwise, off at evenings, nights and most of weekends
- Typical daily load swings are 13 ± 8 klb/hr or 50% average load/boiler ± 30% swings
- The existing 10 hp combustion air fans are controlled by inlet dampers with average motor loads of 80% ±20%
- The excess O_2 in the flue gas at these light and widely varying loads are likely 8%±4% with corresponding boiler combustion efficiencies of 70%±10%
- The more responsive VFD fan speed control should improve boiler efficiency by 2.5%

Savings Calculation

Annual $ savings =

VFD motor load savings = 10 hp x 85% loaded x 0.746 kW/hp x 2,860 hr/yr x $0.0398/kWh x ($1–0.6^3$) = $700/yr

O_2 with auto trim efficiency savings = $350 k/yr x (+2.5% efficiency/70%) = $12,500/yr

Total savings = $700/yr (electrical savings) + $12,500/yr (fuel) = $13,200/yr

Cost Estimate Calculations

Total Cost =

10 hp x $300/hp = $3,000

One excess O_2 in-stack sensor with controller to trim air by VFD = $30,000 installed

Total installed cost = A + B = $3,000 + $30,000 = $33,000 installed

Table 16 lists the economic and benefits from implementing ECM HP-01.

Table 16. ECM HP-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$13.2K
Capital Cost ($)	$33.0K
Simple Payback (years)	2.5
Comments	Capital project

Status/Recommendations for Further Work

The key to this ECM is base load one existing boiler during morning startup and winter heating periods at 60 percent or so load and to use the newly equipped "load following" boiler to efficiently control excess O_2 during 80 percent of the day's normal load variation. Prepare an RFP for vendor/contractor bids.

ECM HP-02

Facility: Fort Leonard Wood

Area: Heating plants Building No. 2351, Specker 1021, 311, and all other associated distribution systems

Description: Insulate all bare and poorly insulated aboveground steam and HW lines and all other justifiable distribution system piping for the four central steam/hot water plants

Background

Approximately 50 ft of 10-in. diameter steam header piping has no insulation. This is an example of possibly many areas in the many miles of extensive steam and/or high temperature hot water distribution system for the four heating plant systems. The rule of thumb for insulating bare steam lines is that 2 in. of insulation will reduce the heat loss from uninsulated lines by 90+ percent with a 1 to 3-yr payback. Properly insulated steam or high temperature hot water distribution systems have 2 to 4 percent convection, conduction and radiation losses

while poorly insulated, long distribution systems can have 10 percent or more annual losses.

Descriptive Scope

Insulate bare 10-in. diameter steam line and all other justifiable distribution system piping for the four central steam/hot water plants.

Data Used for Economics

- Fort Leonard Wood annual heating costs are $9.6 million. See OLB fuel Figure 11.
- Approximately 10 percent of this cost is losses from 5+ miles of pipe, flanges, and valves.
- Approximately 5 of the 10 percent is judged to be improperly insulated or without insulation.
- Approximately 90 percent of these system heat losses can be eliminated.
- Typically 5 percent of the distribution system represents 95 percent of the opportunity.
- The installed cost of insulation averages $30/ft.

Savings Calculation

Annual $ savings = $9.6 million/yr x 10% losses x 5% of system need insulation x 90% losses eliminated = $43,200/yr

Cost Estimate Calculations

Total Cost =

Installed cost = 5 miles x 5,280 ft/mi x 5% distribution system x $30/ft = $33,750

Table 17 lists the economic and benefits from implementing ECM HP-02.

Table 17. ECM HP-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$43.2K
Capital Cost ($)	$33.8K
Simple Payback (years)	0.8
Comments	Capital Project

Status/Recommendations for Further Work

1. Have reputable vendors and contractors survey the entire aboveground steam and high temperature hot water distribution systems, specifically identifying the assumed 5% of the system where 95% of the opportunities are.

2. Determine economics (net annual savings, installed cost, and simple payback) on individual segments of the system – likely 50 or more target areas. An example is the 50 ft of bare pipe in the laundry heating plant. Insulation vendors have software that quickly calculates project economics.

ECM HP-03

Facility: Fort Leonard Wood
Area: Heating Plant Building No. 2351
Description: Install "in-stack" economizer to heat boiler feed water for Heating Plant No. 2351.

Background

The boilers in HP No. 2351 do not have economizers to preheat boiler feed water. A substantial amount of cold boiler make up water is required due to many failed steam traps. The typical boiler efficiency can be improved by 4 to 5 percent if an economizer is available to recover heat from the flue gas stack for use in preheating boiler make up water.

Descriptive Scope

Install low budget economizer directly in the existing boiler stack by "suspending" a tube bundle in the reinforced/stabilized stack. Pipe boiler feed water from the BFW pump through the economizer to raise the temperature from approximately 200 °F to approximately 280 °F, thereby reducing the flue gas exhaust temperature from the current range of 350 to 430 °F, depending on boiler load, to 300 to 360 °F.

Data Used for Economics

- Annual fuel consumption is $335K/yr.
- Existing annual average boiler efficiency is 70 ± 10 percent.
- The proposed "low budget economizer" to preheat BFW typically saves 3 to 5% of fuel costs. This work assumes 4%, even though it is easy to make 100 psi steam from boiler exhaust heat.
- The cost to install a "low budget in-stack economizers" for small (<20,000 lb/hr) is $2,000/million Btu.
- The target boiler is 17 million Btu/hr.

Savings Calculation

Annual $ savings = $335K/yr x 4% savings = $13,400/yr

Cost Estimate Calculations

Installed Cost = 17 million Btu/hr x $2,000 installed cost per million Btu/hr = $34,000

Table 18 lists the economic and benefits from implementing ECM HP-03.

Table 18. ECM HP-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$13.4K
Capital Cost ($)	$34.0K
Simple Payback (years)	2.5
Comments	Capital project

Status/Recommendations for Further Work

Identify approved vendors and contractors for solicitation of requests for proposals.

ECM HP-04

Facility: Fort Leonard Wood

Area: Heating Plant Building No. 2351 and Laundry

Description: Optimize 100 psi steam to meet warm weather HP No. 2351 requirements.

Background

It costs slightly more to produce steam at 100 psi than it does to produce steam at somewhat lower pressures. This ECM suggests that the boiler pressure set point be optimized at less than 100 psi for most of the year when steam loads are less than peak periods. The pressure set point for the boilers that supply steam to the laundry is maintained at a constant setting of 100 psi steam. The laundry operations only require 100 psi during the coldest days of winter when steam production is high resulting in high distribution system pressure drop. During other times of the year, when steam loads are less, the laundry can operate with less than 100 psi steam pressure.

Descriptive Scope

Optimize boiler pressure set points to average less than 100 psi based on seasonal steam loads.

Data Used for Economics

- The laundry boilers consume 350K/yr of fuel.
- The boiler fuel consumption is reduced by 0.3% for each 10 psi lower pressure.
- It is assumed that the average boiler set point can be set at 90 psi during the spring and fall and 80 psi during the summer to average 90 psi throughout the year.

Savings Calculation

Annual $ savings = $ 350K/yr x 0.3% = $1,050/yr

Cost Estimate Calculations

Total Cost = zero

Table 19 lists the economic and benefits from implementing ECM HP-04.

Table 19. ECM HP-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$1.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam dunk

ECM HP-05

Facility: Fort Leonard Wood
Area: Heating Plant Building No. 2369
Description: Optimize HW temperature at significantly lower levels and control off of HW return temperature instead of HW supply temperature.

Background

The current practice of controlling the hot water supply temperature at 360 °F constantly throughout the year results in unnecessarily high system losses. A fundamental concept in the optimization of energy systems is to deliver energy

(hot water in this case) to the legitimate process end users (building heat, showers, etc.) on an "as needed basis." So, for the Post's central HW etc., heating plants this would call for controlling the HW system from the return temperature (not supply temperature) to always make sure the last user of the loop is provided high enough temperature HW. Additionally, the HW return temperature set point should not be held constant. It should rather be adjusted seasonally with much lower temperature levels being satisfactory during spring, summer and fall.

Descriptive Scope

Control HW system temperature off of return temperature (not supply temperature) and adjust to lower levels during periods of warm weather and otherwise low demand.

Data Used for Economics

- The fixed system losses through miles of underground piping and direct leaks are estimated to be 5 MMBtu/hr.
- The current HW supply temperature is controlled at a constant 360 °F.
- The HW return temperature can be adjusted to lower levels based on seasonal heating requirements and post occupancy levels. If it is possible to routinely adjust the HW return temperature for an average supply of 330 °F annually instead of its current annual average of 360 °F for a 60 °F average outside pipe temperature, then the system heat losses will be proportionally less based on the lower ΔT.
- The pressure due to the lower temperature setting will be reduced by approximately 40 psig, from 280 to 240 psi for proportionally lower leak rates.
- The system leak rate (make up) is assumed to be 5,000 gpd.
- Fuel cost for the 2369 Heating Plant are $875K/yr at an average cost of $10.15/MMBtu (85%NG, 15% FO).

Savings Calculation

Reduced insulation losses =

[1- (330-60)/(360-60)] x 5 MMBtu/hr x 8760 hr x $10.15/MMBtu = $44,500/yr

Reduced fuel cost from heat in HW leaks =

(1-240/280) x 5,000 gpd x 8.33 lb/gal x 365 days/yr x 330 °F x 1Btu/lb °F x $10.15/1,000,000Btu = $7,300/yr

Reduced water cost from leaks =

(1-240/280) x 5 kgal/day x 365 days/yr x $0.73/kgal = $200/yr

Total savings = 1 + 2 + 3 = $44,500 + $7,300 + $200 = $52,000/yr

Cost Estimate Calculations

Total Cost = $0

Table 20 lists the economic and benefits from implementing ECM HP-04.

Table 20. ECM HP-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$52.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam Dunk

ECM HP-06

Facility: Fort Leonard Wood

Description: Adjust barracks window opening to meet ventilation requirements

Area: 600, 700, 800, and 1000 complexes.

Background

The current practice of leaving barracks windows wide open for long periods of time wastes a significant portion of the building HVAC. There is a justifiable need to occasionally open 4 to 8 windows approximately 6 to 8 in. The addition of ceiling fans would greatly help the barracks ventilation and indoor air quality (IAQ).

Descriptive Scope

Enforce the guidelines for partially opening windows when required for IAQ. Install ceiling fans throughout the buildings to improve ventilation.

Data Used for Economics

- Barracks are supplied winter hot water heat from Heating Plants No. 2396 and No. 1021 which have total annual costs of approximately $2 million/yr. It is estimated that the Post-Wide barracks alone consume 30% of the $2 million for a cost of $600K/yr.
- Heating of the 600, 800, and 1000 barracks complexes are now accomplished with decentralized direct natural gas units. These consume $1.6 million/yr solely for barracks heat or approximately $500K/yr

- Ten of these barracks are also air-conditioned from the central chiller plant in building No. 745. The operating costs for building No. 745 chillers is $800K/yr 20% of which is for barracks (160K/yr). In addition, other barracks are air-conditioned by numerous packaged window-mounted air-conditioning units with an operating cost of $140K/yr.
- Total HVAC for barracks are the sum of 1-3 above totaling $1,400K/yr.
- It is estimated that excessive, unnecessary window opening practices wastes 20% of the $1,400K/yr totaling $280K/yr.
- Enforcing window ventilation policies save 80% of $260K totaling $168K/yr.
- The installation of 20 ceiling fans in each of the 40 barracks at an installation cost of $150/fan will help to enforce the window policy.

Savings Calculation

Annual $ savings = Heating cost ($k/yr) = 600K + 500K totaling 1,100K

Air cost ($k/yr) = 160K + 140K totaling 300K

Savings = 20% of the total heating and air costs (1,400K/yr) totaling $280K/yr

Cost Estimate Calculations

Installation cost = 20 ceiling fans per barracks x 40 barracks x $150 per fan = $120K

Table 21 lists the economic and benefits from implementing ECM HP-06.

Table 21. ECM HP-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$280.0K
Capital Cost ($)	$120.0K
Simple Payback (years)	0.4 years
Comments	

Status/Recommendations for Further Work

If the installation of ceiling fans is not viable or practical there are multiple other solutions on a barracks-to barracks basis.

ECM HP-07

Facility: Fort Leonard Wood
Area: Heating Plant Building No. 1021
Description: Optimize HW temperature at significantly lower levels and control off of HW return temperature instead of HW supply temperature.

Background

The current practice of controlling the hot water supply temperature at 360 °F constantly throughout the year results in unnecessarily high system losses. A fundamental concept in the optimization of energy systems is to deliver energy (hot water in this case) to the legitimate process end users (building heat, showers, etc.) on an "as needed basis." So, for the Post's central HW etc., heating plants this would call for controlling the HW system off of return temperature (not supply temperature) to always make sure the last user of the loop is provided high enough temperature HW. Additionally, the HW return temperature set point should not be held constant, but rather be adjusted seasonally with much lower temperature levels being satisfactory during spring, especially summer and fall.

Descriptive Scope

Control HW system temperature off of return temperature (not supply temperature) and adjust to lower levels during periods of warm weather and otherwise low demand.

Data Used for Economics

- The fixed system losses through miles of underground piping and direct leaks are estimated to be 5 MMBtu/hr.
- The current HW supply temperature is controlled at a constant 360 °F.
- The HW return temperature can be adjusted to lower levels based on seasonal heating requirements and post occupancy levels. If it is possible to routinely adjust the HW return temperature for an average supply of 330 °F annually instead of its current annual average of 360 °F for a 60 °F average outside pipe temperature, then the system heat losses will be proportionally less based on the lower ΔT.
- The pressure due to the lower temperature setting will be reduced by approximately 40 psig, from 280 psi to 240 psi for proportionally lower leak rates.
- The system leak rate (make up) is assumed to be 3,000 gpd.
- Fuel costs for the No. 1021 Heating Plant are $1,280K/yr at an average cost of $10.15/MMBtu (85%NG, 15% FO).

Savings Calculation

1. Reduced insulation losses =

   1 – (330-60)/(360-60)] x 5 MMBtu/hr x 8760 hr x $10.15/MMBtu = $44,500/yr.

2. Reduced fuel cost from heat in HW leaks =
   (1-240/280) x 3,000 gpd x 8.33 lb/gal x 365 days/yr x 330 °F x 1Btu/lb °F x $8.15/1,000,000Btu = $3,500/yr.
3. Reduced water cost from leaks =
   (1-240/280) x 3Kgal/day x 365 days/yr x $0.73/kgal = $100/yr

Total savings = 1 + 2 + 3 = $44,500 + $3,500 + $100 = $48,100/yr

Cost Estimate Calculations

Total Cost = $0

Table 22 lists the economic and benefits from implementing ECM HP-07.

Table 22. ECM HP-07 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$48.1K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam Dunk

ECM HP-08

Facility: Fort Leonard Wood
Area: Building No. 2369, Specker Heating Plant Complex
Description: Install VFD on each 20 hp combustion air fan for two hot water generators (HWG) in HP No. 2369.

Background

Building No. 2369 heating plant provides centrally distributed, high-temperature, high-pressure, HW to the Specker complex of 20+ buildings, barracks, mess halls, etc. Two HWGs (2 x 24 MBtu/hr) operate throughout the winter at varying loads from 55 to 85 percent loaded (average 70 ±15 percent) and 40 to 60 percent loaded (50 ±15 percent) for an annual average load of 60 percent throughout the year. The combustion air fans are controlled by inlet dampers and there is no excess O_2 measurement for auto trim of fuel-to-air ratio. The result is excessive consumption of combustion air fan motor energy over the wide load swings (40 to 85 percent) and excessive fuel consumption due to varying boiler efficiencies of 70 ±10 percent, again for the same reason, wide swings in daily loads of 60 ±20 percent.

Descriptive Scope

Install on each boiler a VFD on the combustion air fan and excess O_2 measurement for automatic O_2 trim control by the VFD.

Data Used for Economics

- Combustion air fan motors are 20 hp.
- Average annual load and variation is 60%±20%..
- Operating hours = 8700 hrs/yr.
- Existing fan motor load with damper control is 80% ±10%.
- The motor efficiency is 85%.
- Electricity costs $0.0398/kWh, including demand.
- Existing annual boiler fuel cost is $875K/yr.
- Existing boiler efficiency is 70%±10% with excess O_2 averaging 6%±2%; a new boiler efficiency with O_2 control to new VFDs should be 73%±2% rather than 70%±3%.

Savings Calculation

1. Annual $ savings =

   VFD fan motor savings = 2 x 20 hp x 0.746 kW/hp x (80% loaded/85% efficient) x 8700 hrs/yr x $0.0398/kWh x $(1-0.6^3)$ = $7,600/yr

2. Fuel savings w/+3% efficiency = $875K/yr x (0.03/0.70) = $37,500/yr

Total savings = 1+ 2 = $7,600/yr + $37,500/yr = $45,100/yr

Cost Estimate Calculations

Total Cost =

VFD = 2 x 20 hp x $250/hp = $10,000 installed

O_2 control = 2 x $30,000 = $60,000 installed

Total installed cost for A + B = $70,000 installed

Table 23 lists the economic and benefits from implementing ECM HP-08.

Table 23. ECM HP-08 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$45.1K
Capital Cost ($)	$70.0K
Simple Payback (years)	1.6
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

ECM HP-09

Facility: Fort Leonard Wood

Area: Building No. 2369, Specker Heating Plant Complex

Description: Install VFD on 60 hp HW recirculation pumps in HP No. 2369.

Background

The existing HW recirculation pumps are throttled or allowed to by-pass their loop at the heating plant to control flow throughout the large daily and seasonal load swings. This wastes a significant amount of electrical pump motor energy.

Descriptive Scope

Install a VFD on each 60 hp HWG recirculation pump to provide the capability of efficiently matching HW flow to the customer's demand on an "as needed" basis.

Data Used for Economics

- Existing HW recirculation pump for each HWG is 60 hp, 90% loaded and 90% efficient
- Average annual flow rate load variation is 70%±20%
- Operating hours are 8700 hrs/yr
- Electricity cost is $0.0398/kWh, including demand
- A 60 hp VFD cost $200/hp

Savings Calculation

Annual $ savings =

2 x 60 hp x 0.746 kWh/hp x (90% loaded/90% efficient) x 8700 hr/yr x $0.0398/kWh x (1-0.7^3) saved

= 778,800 kWh/yr x $0.0398/kWh x 65.7% saved = $20,400/yr

Cost Estimate Calculations

Total Cost =

Installed cost = 2 x 60 hp x $200/hp = $24,000

Table 24 lists the economic and benefits from implementing ECM HP-09.

Table 24. ECM HP-09 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$20.4K
Capital Cost ($)	$24.0K
Simple Payback (years)	1.2
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

ECM HP-10

Facility: Fort Leonard Wood

Area: Building No. 1021 Heating Plant

Description: Install VFD on operating HWG combustion air fan plus O_2 control.

Background

Building No. 1021 has two large HWG at 46 MBtu/hr capacity. Only one unit is operated even in the coldest weather at peak load conditions. A sensor for excess O_2 measurement was once installed; however, it was not of adequate quality, accuracy, and reliability due to limited funding.

Descriptive Scope

Install a VFD on the operating HWG, 30 hp combustion air fan to load follow with an excess O_2 signal from a new zirconium oxide sensor in the stack. These additions will optimize excess O_2 at lower levels, for higher efficiency over the wide ranges of daily and seasonal load swings and also significantly reduce fan motor load. This ECM is identical in principle to ECM HP-09 for HWGs in Building No. 2359.

Data Used for Economics

- One 30 hp combustion air fan
- Annual average load variation of 70%±15%
- Operating hours of 8700/yr
- Existing fan motor with damper control is loaded at 85%±10%
- The motor efficiency is 88%
- Electricity cost = $0.0398/kWh including demand charges

- Existing annual boiler fuel cost $1,280K/yr
- Existing average boiler efficiency is 75% ±5% with excess O_2 averaging 5% ±2%
- New boiler efficiency with O_2 control will be 77% vs. 75%
- A 30 hp VFD cost $250/hp installed.

Savings Calculation

1. Annual $ savings =

   VFD fan motor savings = 1 x 30 hp x 0.746 kW/hp x (85% loaded/99% efficient) x 8700 hrs/yr x $0.0398/kWh x (1 – $[0.7]^3$) = $4,900/yr

2. Fuel savings with +2% efficiency gain =

   $1,280K/yr x (2%/75%) = $39,000/yr

Total savings = 1 + 2 = $4,900/yr + $34,100/yr = $39,000/yr

Cost Estimate Calculations

Total cost =

VFD = 1 x 30 hp x $250/hp = $7,500 installed

O_2 control = 1 x $30,000 = $30,000 installed

Total installed cost = A + B = $7,500 (VFD) + $30,000 ($O_2$ control) = $37,500

Table 25 lists the economic and benefits from implementing ECM HP-09.

Table 25. ECM HP-10 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$39.0K
Capital Cost ($)	$37.5K
Simple Payback (years)	1.0
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

ECM HP-11

Facility: Fort Leonard Wood

Area: Building No. 1021 Heating Plant

Description: Install VFD for HW recirculation pump for lead HW generator.

Background

Additional savings can be realized with better load following performance if a VFD were installed on the 75 hp recirculation pump. This ECM is identical in principle to ECM HP-10 for Building No. 2369.

Descriptive Scope

Install a VFD on the 75 hp lead HWG recirculation pump to provide the capability of efficiently matching HW flow to the customer's demand on an "as needed" basis.

Data Used for Economics

- Existing HW recirculation pump for HWG is 75 hp, 90% loaded and 92% efficient
- Average annual flow rate load variation is 75%±20%
- Operating hours are 8700 hrs/yr
- Electricity cost is $0.0398/kWh, including demand
- A 75 hp VFD cost $200/hp.

Savings Calculation

Annual $ savings =

1 x 75 hp x 0.746 kW/hp x (90% loaded/92% efficient) x 8700 hrs/yr x $0.0398/kWh x (1-$0.75^3$)

= $11,000/yr

Cost Estimate Calculations

Total Cost =

Installed cost = 1 x 75 hp x $200/hp = $15,000

Table 26 lists the economic and benefits from implementing ECM HP-11.

Table 26. ECM HP-11 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$11.0
Capital Cost ($)	$15.0
Simple Payback (years)	1.4
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

6 Fort Leonard Wood Laundry Results

This Chapter shows ECMs that were developed from onsite work done in the laundry operation (Table 27).

Object Statement: Identify ECM solutions that will optimize energy cost (higher efficiency and/or lower consumption) at equal or better production rate, product quality, safety, or morale.

Table 27. Laundry (L) ECMs summary.

ECM	Energy Conservation Measure (Descriptive scope: what?, where?, why?)	Category (SD, LU, etc.)	Net Savings ($k/yr)	Capital Cost ($k)	Simple Payback (yrs)
L-01	Install VFD on extractor motor to optimize extractor cycle time for a 5% increase in output	CP	$100.0	$75.0	0.8
L-02	Repair failed steam traps that waste steam in laundry	LU	$28.8	$0.0	Immed.
L-03	Insulate bare steam and HW valve bodies and fittings with soft cover, snap-on/off insulation	CP	$7.2	$8.0	1.1
L-04	Repair 5 gpm cooling water leak on air compressor	LU	$1.8	$0.0	Immed.
	Total		$137.8	$83.0	0.6
Abbreviations: ECM Area and Categories PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost); LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical; PET = follow up by the PET					

Task

Identify CCIs for Laundry that, if solved, will save $$ and improve the end user operations (CCIs = problems or opportunities that waste a significant amount of $$; cf. Table 28).

Table 28. Laundry problems or opportunities that waste a significant amount of $$.

CCI	Description (what and where)	CCI Cost Calculation	Estimated cost
1.	Cycle times too long in extractor	See 10% what if	$280,000 (contributes to this amount)
2.	Drying time too long for same productivity	See 10% what if	$280,000 (contributes to this amount)

CCI	Description (what and where)	CCI Cost Calculation	Estimated cost
3.	Don't know how many times a piece has been recycled through re-wash	\$3.4 million x 0.5% = \$17,000	\$17,000
4.	Leaking cooling water on air compressor	Estimate = 5 gal/min. x 525,400 min/yr x \$0.7/1000 gal = \$1,838	\$1,838
5.	Optimize boiler pressure set point	\$350,000 x 1.5% improved = \$5,250	\$5,250
6.	Use less expensive boiler fuel		
7.	Too many steam trap losses and nobody is responsible	1,000 lb/hr x 4000 hrs /yr x \$10/1000 lb = \$40,000/yr	\$40,000/yr
8.	Some steam valves, flanges and piping has no or too little insulation	\$350,000 x 3% = \$10,500	\$10,500
9.	Low efficiency standard V-belts in use	548,071 kWh x 1.5% x 3.9¢/kWh	\$300

Revenue and Operating Cost Analysis – Laundry (GOCO)

Purpose: To determine the economic contribution (k\$/yr) from incremental process-related improvements in the laundry operations. These are referred to as the "10 percent What If" benefits from potential process optimization initiatives (Table 29).

Table 29. Revenue and operating cost analysis – Laundry (GOCO).

No.	Description/Basis	Existing k\$/yr	+10% throughput
1.	Revenue: 7 million pieces/yr	\$3,600	\$360
2.	Operating Cost:		
	2a. Labor (hourly 20% variable)	\$2,000	\$40
	2b. Energy/utilities (20% variable) -Electricity \$52.4K/yr -Fuel \$457.8K/yr -Water \$26.0K/yr Subtotal \$536.2K/yr	\$536	\$11
	2c. Operating Supplies (95% variable)	\$300	\$29
	2d. G&A and other (0% variable)	\$200	\$0
	Total Operating Cost	\$3,436	\$80
3.	Profit (No. 1–2)	\$164	\$280
Summary for "+10% What If" benefits			**k\$/yr**
1. New profit from +10% Throughput			\$280*
2. New profit from +10% Hourly labor			\$160**
3. New profit from +10% Energy			\$43
4. New profit from +10% Materials and supplies			\$1

No.	Description/Basis	Existing k$/yr	+10% throughput
1.	Revenue: 7 million pieces/yr	$3,600	$360
2.	Operating Cost:		
	2a. Labor (hourly 20% variable)	$2,000	$40
	2b. Energy/utilities (20% variable) -Electricity $52.4K/yr -Fuel $457.8K/yr -Water $26.0K/yr Subtotal $536.2K/yr	$536	$11
	2c. Operating Supplies (95% variable)	$300	$29
	2d. G&A and other (0% variable)	$200	$0
	Total Operating Cost	$3,436	$80
3.	Profit (No. 1–2)	$164	$280
Summary for "+10% What If" benefits			**k$/yr**
* Not applicable to Fort Leonard Wood laundry operation since they are unable to take in outside work ** This is real opportunity for Fort Leonard Wood if the laundry processes can be de-bottlenecked by 10% to produce 5.5 days of laundered goods in only 5 days.			

ECM L-01

Facility: Fort Leonard Wood

Area: Laundry (L)—Penn Enterprises

Description: Install VFD on extractor motor to optimize extractor cycle time and dryer cycle times for a 5 percent increase in output eliminating half-day Saturday Laundry operation.

Background

The laundry operating schedule average 5.5 days/wk for 52 wks/yr to accommodate 7 million pieces of laundry per year. A routine bottleneck in operating throughputs is the cycle times in the extractor and the product mix processed through the laundry varies widely from sleeping bags with very long cycle times to light fabric with very short cycle times.

This is a classical example of optimizing the run conditions of the first process step, in this case, the extractor RPM and cycle time for each class of laundered goods. The objective is to reduce the combined cycle time for both the extractor and the dryers. The extractor cycle is a key factor in reducing cycle times to increase throughput. Unfortunately, the RPM of the extractors have constant motor-driven speeds with no capability to adjust RPM speed. A VFD addition to the extractor motor drivers provide precise speed control from approximately 60 to

120 percent, thereby optimizing the load size and the RPM for each type of goods for short times and/or long cycle times.

Descriptive Scope

Install VFD on up to 10 of the 30 hp extracted motors to optimize the overall extraction plus dryer cycles for each type of laundered goods. The expected result is a 5 to 10 percent shorter cycle time for a 5 to 10 percent greater production rate. This can possibly eliminate the typical half day Saturday scheduled work.

Data Used for Economics

- 10 extractors each with 30 hp motor drives.
- An average of 5% increase in throughput can shorten the work week from 5.5 days/wk to 5.0 days/wk resulting in a 5%reduction the $2000K/yr labor costs. (See details in the budget and operating cost analysis for the yearly laundry operations.
- A 30 hp VDF costs $250/HP.

Savings Calculation

Annual $ savings =

$2,000K/yr of hourly labor x 5% = $100,000/yr (labor savings)

Cost Estimate Calculations

Total Cost = 10 units x 30 hp x $250/hp = $75,000/yr.

Table 30 lists the economic and benefits from implementing ECM L-01.

Table 30. ECM L-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$100.0K
Capital Cost ($)	$75.0K
Simple Payback (years)	0.8
Comments	Capital project

ECM L-02

Facility: Fort Leonard Wood

Area: Boiler house Bldg No. 2351 and Laundry

Description: Repair failed steam traps that waste steam in the Laundry.

Background

Penn Enterprises is very interested in eliminating wasted steam because they are charged for the usage. Delegation of the steam trap maintenance responsibility has apparently been unresolved for several years; the maintenance is not done regularly. The result is many of the steam traps have failed partially open, allowing "live" steam to enter the condensate return system and to vent from the condensate receiver into the boiler house, which is a waste of energy and dollars, and "looks" like a negative environmental plant emission.

Descriptive Scope

Determine the responsible party for steam trap maintenance and repair/replace failed traps. A visual count done by Penn Enterprises found a total of 122 steam traps in the laundry. It is estimated that approximately 15 percent of the steam traps need to be repaired and 15 percent need to be replaced. Initially (year No. 1), this is best done by an outside steam trap "specialist" (not necessarily a steam trap vendor).

Data Used for Economics on Existing System

- Penn Enterprises, Inc. counted 122 steam traps throughout the laundry facility. The cumulative result of high trap failures is a 20+ ft steam plume of live steam from the condensate receiver in the boiler house.
- The trap losses are estimated to average 1,000 lb/hr for 10 hrs/day, 6 days/wk, 52 wks/yr.
- Steam cost is $7.80/MMBtu fuel, at 70% efficiency = $10.40/klb.
- 15% of the 122 traps are estimated to be partially failed and will cost $100 each to repair.
- 15% of the 122 traps are recommended for replacement at $300 each.

Savings Calculation

Annual $ savings =

Gross savings = 1 klb/hr x 10 hrs /day x 6 days/wk x 50 wks/yr x $10.40/klb = $31.2K/yr

Less annual expense (see item 4 below) = $2.4K/yr

Net Annual Savings = $28.8K/yr

Cost Estimate Calculations

Total Cost =

Repair cost = 15% x 122 traps x $100/trap (repair) = $1,800

Replacement cost = 15% x 122 traps x $300/trap (replace) = $5,500

Total expense (every 3 years) = \$1,800 + \$5,500 = \$7,300

Total expense/yr = \$7,300 (expense over 3 years)/3 years = \$2,400/yr

Table 31 lists the economic and benefits from implementing ECM L-02.

Table 31. ECM L-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings (\$/yr)	\$28.8K
Capital Cost (\$)	\$0.0K
Simple Payback (years)	Immediate
Comments	Lay-up

Status/Recommendations for Further Work

Have reputable steam trap supplier survey and repair/replace all failed traps. Thermodynamic disc or impulse traps and orifice type traps are not as efficient as thermostatic designs.

ECM L-03

Facility: Fort Leonard Wood,

Area: Boiler house Bldg No. 2351

Description: Insulate bare steam and hot water valve bodies and fittings with soft cover, snap-on/off insulation (laundry).

Background

It is common that, while steam and HW pipes are generally insulated, a number of steam and hot water valve bodies, flanges, and fittings are left uninsulated with temperature range of 160 °F (HW) to 340 °F (Steam).

Descriptive Scope

Install soft cover, snap-on insulation covers on all bare valve bodies and associate fittings that are greater or equal to 160 °F.

Data Used for Economics

- It is estimated that there are approximately 80 uninsulated hot valves bodies and fittings with an average temperature of 250 °F.
- The cost per valve cover (1.5-3.0-in. globe valve) is \$100 each.
- Uninsulated 2-in. valve at 250 °F loses 3000Btu/hr.

- The covers reduce 70% of the heat loss.
- Fuel is $7.00/mmBtu (average for HP No. 2351).
- Average boiler efficiency is 65%.
- Heat loss is over 4000 hrs/yr.
- 70% of heat loss is eliminated with covers.
- Valve covers are $100 each.

Savings Calculation

Annual $ savings =

80 valves x 3000 Btu/hr x 70% reduction x 4000 hrs/yr x $7.00/mmBtu/65% efficiency = $7,200.

Cost Estimate Calculations

Total Cost = 80 valve covers at $100/cover = $8,000

Table 32 lists the economic and benefits from implementing ECM L-03.

Table 32. ECM L-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$7.2K
Capital Cost ($)	$8.0K
Simple Payback (years)	1.1
Comments	Capital project

Status/Recommendations for Further Work

ECM L-04

Facility: Fort Leonard Wood

Area: Boiler house Bldg No. 2351 and Laundry

Description: Repair 5 gpm cooling water leak on air compressor.

Background

A leak on the air compressor cooling water system is estimated to be approximately 5 gpm. This is city water.

Descriptive Scope

Repair water leak ("once through" city water) on the air compressor cooling system.

Data Used for Economics

- Leak rate is estimated at 5 gpm, continuous 7 x 24.
- City water costs $0.70/kgal.
- Repair cost is 1 hour @ $30/hr.

Savings Calculation

Annual $ savings =

Water savings = 5 gpm x (60 minutes/hr x 24 hrs /day x 356 days/yr)/1,000 gal x $070/kgal = $1,840/yr

Repair Cost = $30

Net Savings = $1,810/yr

Cost Estimate Calculations

Total Cost =

No capital cost – see net savings calculation for repair cost

Table 33 lists the economic and benefits from implementing ECM L-04.

Table 33. ECM L-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$1.8K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay up

7 Fort Leonard Wood Maintenance Complex Results

Object Statement: Identify ECM solutions that will optimize energy cost (higher efficiency and/or lower consumption) at equal or better TAT, maintenance quality, safety, or morale (Table 34).

Table 34. Maintenance Complex ECMs summary.

ECM	Energy Conservation Measure (ECM) Descriptive scope: what, where, why	Category (SD, LU, etc.)	Net Savings ($k/yr)	Capital Cost ($k)	Simple Payback (yrs)
MC-01	Upgrade lighting in paint booth to reduce TAT	CP	$3.5	$5.0	1.4
MC-02	Analyze the entire HVAC system and make appropriate modifications	CP	$335.0	$550.0	1.6
MC-03	Replace high traffic overhead doors and seals to greatly reduce building heating loads.	CP	$14.4	$90.0	6.3
MC-04	Initiate predictive/preventative maintenance to reduce TAT	CP	$135.0	$150.0	1.1
MC-05	Identify and repair compressed air leaks in WV and HS areas	LU	$0.8	$0.0	Immed.
MC-06	Re-engineer tail-pipe suckers in heavy shop that do not work properly.	PET	$13.4	$13.4	1.0
	Total		$502.1	$808.4	1.6
Abbreviations, ECM area and categories: PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost); LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical; PET = follow up by the PET					

Critical Cost Issues

Task: Identify CCIs for Maintenance Complex that if solved will save $$ and improve the end user operations; CCIs = problems or opportunities that waste a significant amount of $$ (Table 35).

Table 35. Critical cost issues, maintenance complex.

CCI	Description (what and where)
1.	No predictive/preventative maintenance program for overhead doors shop air compressors overhead lift cranes HVAC
2.	Excessive wait time for supplies
3.	Inadequate ventilation in welding shop (IAQ)
4.	Overhead door designs are poorly designed (over 50 OH doors)
5.	No meters on energy supply and process consumption can't manage what you can't measure
6.	HVAC systems throughout complex don't work hurting morale and productivity, efficiency
7.	Takes too long to renew or replace a contract
8.	Blast booth lights inadequate, net direct (ceiling only) and dirty
9.	Ventilation fan in wheeled vehicle shop does not meet the demand
10.	Too many compressed air leaks in: compressor room in Heavy Shop painter guns left on during break
11.	Moisture problems with all compressed air systems
12.	Thermostats do not control the system

Task: Identify CCIs for Paint/Blast that if solved will save $$ and improve the end user operations; CCIs = problems or opportunities that waste a significant amount of $$ (Table 36).

Table 36. Critical cost issues – paint/blast that waste a significant amount of $$.

CCI	Description (what and where)
1.	Summer heat is tough on guys with protective clothing
2.	Inadequate lighting in P&B booth requires moving vehicle to see results
3.	No heat in paint booth can cause paint to run and stop production
4.	Inconsistent, unpredictable work load (especially P&B) because of changing mission
5.	Takes too long to sweep up media in blast booth
6.	No back up system for breathing air in P&B shop
7.	Filter changes in paint booth consume too much time and slow production
8.	Humidity sometimes causes painted part problems

Task: Identify CCIs for/in Wheeled Vehicle and Heavy Shop that if solved will save $$ and improve the end user operations; CCIs = problems or opportunities that waste a significant amount of $$ (Table 37).

Table 37. Critical cost issues – Wheeled Vehicle and Heavy Shop that waste a significant amount of $$.

CCI	Description (what and where)
1.	Ventilation/exhaust system in Heavy Shop is old and worn out (high maintenance) and will not handle the volume of exhaust.
2.	Space heaters (Modine HW unit) above work bays are not properly controlled
3.	System vs. Local Purchase. Not enough flexibility in purchase of parts/materials results in higher cost (+25%), longer time (10 days vs. 3 days) and sometimes the wrong part. Examples: >$2500 required to be contracted (very slow – months not weeks)
4.	Biggest TIME wasters in Heavy Shop and Wheeled Vehicles: • Contract procurement • Too much wrench turner's time on front end and back end of actual job (ex: recoverable items – like transmissions and tires) • Mandatory training • Sometimes installed parts do not work (rarely) and must do over
5.	Biggest ENERGY wasters in Heavy Shop and Wheeled Vehicles: • Lack of proper ventilation. • The vehicle exhausters in Heavy Shop are too stiff (do not work) so doors must be opened in the winter. • Problem with open doors exist 30% of winter season. • Modine heaters in Wheeled Vehicle shop run when not needed (30% or > of working hrs/wk). This wastes HW and affects comfort. • Overhead doors/seal /slow openers in Wheeled Vehicle shop waste a lot (25 to 50 percent) of work area heat • Are night and week end "set back" available on heating for both shops? • Fans on heating/ventilation are constant speed • Compressed air leaks in Wheeled Vehicles and Heavy Shop • Lighting – always off during nights and weekends. Don't think there are any savings here • Office HVAC: Apparently, the airside operates 24x7 and the individual office temperature controls typically (70% of the time) do not control properly (for example: heating when outside temperature is 45 to 70°F works OK. When <45°F offices too cold in the 60s. When >70°F offices are too hot in the 80s).

Revenue and Operating Cost Analysis – Purpose

To determine the economic contribution (k$/yr) from incremental process-related improvements in the DOL maintenance complex. These are referred to as the "10 percent What If" benefits from potential process optimization initiatives (Table 38).

Table 38. Maintenance Complex "10% What If" benefits from potential process optimization initiatives.

No.	Description/Basis	Existing k$/yr	+10% throughput
1.	Operating budget:	$12,000	$1,200$
2.	Operating cost:		
	2a. Labor (20% variable)	$7,000	$140
	2b. Energy/utilities (20% variable) • Electricity $350.0K/yr • Fuel $130.0K/yr • Water $15.0K/yr • Subtotal $495.0K/yr	$495	$10
	2c. Operating Supplies (95% variable)	$4,000	$380
	2d. G&A and other (0% variable)	$505	$0
	Total Operating Cost	$3,436	$530
3.	Residual Value	$164	$670

Summary for "+10% What If" benefits	k$/yr
1. New value from +10% Throughput	$670*
2. New value from +10% Labor (improved productivity)	$560**
3. New value from +10% Materials and supplies	$20
4. New value from +10% Energy	$40

* Not applicable at Fort Leonard Wood, since the operation does not take in outside work.

** This value does not suggest reduced labor levels, but rather the value of improved TAT from the existing labor resources.

ECM MC-01

Facility: Fort Leonard Wood

Area: Maintenance Complex [MC]

Description: Upgrade lighting in paint booth to reduce TAT.

Background

There is inadequate lighting in the paint booth and this requires that 50 percent of the vehicles be moved out of the booth for inspection and 25 percent to be moved back in for touch up/corrective action.

Descriptive Scope

Install 10 new lighting fixtures on walls of paint booth.

Data Used for Economics

- Poor lighting wastes 10% of $44,000 operating budget for paint shop.
- Better lighting will solve 80% of the problem or $3,500/yr.
- Each new lighting fixture will cost $500 each.

Savings Calculation

Annual $ savings =

$44,000/yr (paint booth operating budget) x 10% (waste from poor lighting) x 80% (waste reduction from new lighting) = $3,500/yr

Cost Estimate Calculations

Total Cost =

10 new lighting fixtures x $500/fixture (installed) = $5,000

Table 39 lists the economic and benefits from implementing ECM MC-01.

Table 39. ECM MC-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$3.5K
Capital Cost ($)	$5.0K
Simple Payback (years)	1.4
Comments	Capital project

ECM MC-02

Facility: Fort Leonard Wood
Area: Maintenance Complex
Description: Analyze the entire HVAC system including: system supply problems, air side balance and controls.

Background

The maintenance complex space heating and cooling systems have had many problems for years. The areas simultaneously vary from too hot to too cold and the air-side distribution systems are not properly balanced. Currently the Maintenance Complex does not have the capability to reset temperature set points during “off-duty” time (5 p.m. to 5 a.m., 5 days/wk and on weekends). An additional problem is that the Maintenance Complex is on the end of the HW and cooling system and at times, does not receive adequate supply. Also, the control systems fight each other. At times, they heat and cool at the same time. All

these problems adversely affect morale and worker ability to get the job done. These conditions extend TAT on critical systems.

Descriptive Scope

Analyze and fix the HVAC problems in the maintenance complex. Install "smart" thermostats, programmed to control building conditions.

Data Used for Economics

- The heating systems for the maintenance complex cost $162,000/yr (see OLB-Fuel).
- The cooling systems for the maintenance complex cost approximately $150,000/yr (see OLB electric).
- It is estimated that the combination of problems collectively waste 1/3 of the total annual HVAC bill (1/3 of [$162K/yr + $150K/yr]).
- More significantly, the indirect consequences of 160 maintenance complex workers being too hot or too cold for 50% of the time produces significant distractions, resulting in 10% longer turn-around time than necessary.
- A 10% improvement in TAT for the maintenance complex is worth $800K/yr in value to Fort Leonard Wood. (See "Budget and Operating Cost Analysis."
- Resolution of these HVAC problems is expected to improve TAT by 5%.

Savings Calculation

Annual $ savings =

$670,000/yr (10% TAT improvement) x 50% (5% TAT savings) = $335,000/yr savings

Cost Estimate Calculations

Total Cost =

$100,000 for study, "balancing" and tuning and/or repairing of HVAC controls.
$300,000 is budgeted for adding a booster chiller to chilled water supply.
$150,000 is budgeted for adding a direct-fired hot water tempering system to central hot water loop.

Table 40 lists the economic and benefits from implementing ECM MC-02.

Table 40. ECM MC-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$335.0K
Capital Cost ($)	$550.0K
Simple Payback (years)	1.6
Comments	Capital project

Status/Recommendations for Further Work

Develop RFP for this work.

ECM MC-03

Facility: Fort Leonard Wood
Area: Maintenance Complex
Description: Replace high traffic overhead doors and seals to greatly reduce building heating loads.

Background

The overhead doors open and close too slowly and let cold air into high traffic areas. Also, seals are poorly designed and fail on high traffic doors within a few months resulting in continuous winter air filtration.

Descriptive Scope

Replace five doors in Wheeled Vehicle Shop and Heavy Shop with new, fast action, low infiltration doors to eliminate 80 percent of the 25 percent infiltration (i.e., 80% x 25% = 20%).

Data Used for Economics

- There are at least 50 overhead doors throughout the complex.
- There are five doors in the Wheeled Vehicle Shop and Heavy Shop that are very high passage volume doorways.
- High air infiltration increases building heat load in Wheeled Vehicle and Heavy Shop by 25%.
- The two shops have a combined heating cost of $72,000/yr.
- Replacing five doors in Wheeled Vehicle Shop and Heavy Shop will decrease 80% of the 25% infiltration of cold air.
- Each new door will cost $18,000.

Savings Calculation

Annual $ savings =

$72,000/yr (heating cost in WV and HS) x 20% (reduction from new doors) = $14,400/yr

Cost Estimate Calculations

Total Cost = five new doors x $18,000/door = $90,000 installed

Table 41 lists the economic and benefits from implementing ECM MC-03.

Table 41. ECM MC-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$14.4K
Capital Cost ($)	$90.0K
Simple Payback (years)	6.3
Comments	Capital project

ECM MC-04

Facility: Fort Leonard Wood

Area: Maintenance Complex

Description: Initiate predictive/preventative maintenance to reduce TAT.

Background

There is currently no Predictive Maintenance Program (PMP) in place at the DOL Maintenance Complex for overhead doors, shop air compressors, overhead lift cranes, and HVAC systems. The combination of these factors increases unscheduled downtime of these systems and has a negative impact on TAT.

Descriptive Scope

Implement a predictive/preventative maintenance program for overhead doors, shop air compressors, overhead lift cranes, HVAC systems, and all other critical systems at the DOL Maintenance Complex.

Data Used for Economics

- An effective PMP will reduce TAT by up to 10%. Conservatively credit a PMP with a 5% decrease in TAT.
- An arbitrary ±10% for the entire maintenance complex is valued at $800K/yr. The lack of a PMP adversely impacts TAT for the entire complex operations
- The cost to reduce TAT by 7% includes:
  - first year expenses to design unique, appropriate PMP for the MC ($150K for software)
  - the cost for implementing over a 6 month period ($50K)
  - the cost for ongoing materials, tools, and support each year.

Savings Calculation

Annual $ savings =

TAT improvement = $670,000/10% x 0.5 (5% credit for PMP) = $335,000.

Ongoing cost = $200,000/yr

Net annual savings = $335,000/yr - $200,000/yr = $135,000/yr

Cost Estimate Calculations

Total Cost =

Implementation cost = $150,000

Table 42 lists the economic and benefits from implementing ECM MC-04.

Table 42. ECM MC-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$135.0K
Capital Cost ($)	$150.0K
Simple Payback (years)	1.1
Comments	Capital project

ECM MC-05

Facility: Fort Leonard Wood
Area: Maintenance Complex
Description: Identify and repair compressed air leaks in Wheeled Vehicle and Heavy Shop areas.

Background

Typical industrial repair shops can waste as much as 30 percent of their compressed air production due to leaks. The maintenance complex leaks as a percent of total compressed air production is probably not that high because the actual compressed air consumption is low an the units are shut off during non-work hours.

Descriptive Scope

Initiate a comprehensive leak identification, tag, and repair program initially done through an outside company that is a specialist in compressed air. Continue to support the program internally by repairing leaks as needed on a monthly basis.

Data Used for Economics

- Two 75 hp Sullair rotary screw compressors operating at 60% loaded at 3 cfm/hp for 10 hr/day x 5 days/wk, 50 wks/yr.
- The average leak rate is 30% of the annual compressed air kcf.
- Compressed air/1000 cf @ $0.0398/kWh = $0.13/kcf.
- The leak reduction savings will average 70% of annual leaks.

Savings Calculation

Annual $ savings =

Electricity savings = 75 hp x 3 cfm/hp x 30% leaks x ([2500 h/yr x 60 min/hr]/1000 cf) x $0.13/kcf = $1,300/yr

Annual expense = $2,100 (first year) and $500/yr thereafter

Net annual expense (after 1 year) = $1,300 - $500 = $800/yr

Cost Estimate Calculations

Total Cost =

Initial cost = $2,100

Table 43 lists the economic and benefits from implementing ECM MC-05.

Table 43. ECM MC-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$0.8K
Capital Cost ($)	$0.0
Simple Payback (years)	Immediate
Comments	Lay up

ECM MC-06

Facility: Fort Leonard Wood
Area: Maintenance Complex
Description: Re-engineer tail-pipe exhaust (fume capture) in heavy shop that do not work properly.

Background

The vehicle exhaust systems in the Heavy Shop do not properly connect to the tailpipes. The results are poor fume capture that leads to IAQ problems and worker exposure. This affects TAT.

Descriptive Scope

Defer to PET to find a $13,400 solution to a $13,400/yr problem in TAT.

Data Used for Economics

- This problem collectively increases TAT by 0.2%
- A 10% decrease in TAT = $670,000/yr
- A 0.2% decrease in TAT = $13,400/yr
- Find a $13,400/yr solution for a 1-year payback.

Savings Calculation

Annual $ savings = $13,400

Cost Estimate Calculations

Total Cost = $13,400

Table 44 lists the economic and benefits from implementing ECM MC-06.

Table 44. ECM MC-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	13.4K
Capital Cost ($)	13.4K
Simple Payback (years)	1.0
Comments	PET Evaluate

Status/Recommendations for Further Work

Find a $13,400 solution to this problem for a 1-year payback.

Summary and Conclusions

A total of 26 potential ECMs were identified for the following plant utility systems; Post-wide (PW), Heating Plant (HP), Laundry (L) and Maintenance Complex (MC). A total of 26 of the ECMs were quantified with economics and when implemented, will reduce the post's annual energy and operating costs by approximately $2,617,700. The capital investment required to accomplish these savings is approximately $1,929,300 and results in an average simple payback of 0.7 years.

Since the scope of this project was limited to a few areas of the installation, many additional opportunities for energy savings still exist. The primary areas that are worthy of more analysis include family housing, the barracks complex, and the hospital.

The total savings and cost figures shown above can be somewhat misleading. The actual total of $2,617,700 represents the summation of ECMs that have been evaluated and calculated independently of each other. Also, the estimations used to develop each ECM are assumed to be accurate at ±20 to 40 percent. Finally, the benefit of one ECM may be diminished if another is done because they have interrelated kWh or fuel savings.

Regardless, the overall economics from the ECMs presented indicate great potential and excellent ECM paybacks. From over 100 PEO audits, on average, the "net" or real anticipated savings from all of the ECMs developed is approximately equal to 75 percent of the "gross" savings from a typical audit. This means that of the $2,617,700 in savings that have been calculated with less than a 3-year payback in the audit, approximately $1,963,275 ($2,617,700 x 0.75 = $1,963,275) in actual savings will come from implementing these ECMs. As a result, further engineering analysis and cost estimating are highly recommended.

8 The Process Optimization Assessment at Fort Carson

Site Overview

Fort Carson, the "Mountain Post," is located just south of Colorado Springs at the base of the Rocky Mountains. Fort Carson consists of 138,523 acres, which includes the cantonment area (main post) and training areas down range. The training areas include a wide variety of different vegetation types. Terrain includes open prairies and heavily forested areas, lowlands, wetlands, creek drainages, and mountainous and hilly areas. Fort Carson can accommodate a wide variety of training, including extensive maneuver training (both mounted and dismounted), airborne training, weapons training (including small arms qualification), and tank, artillery, and helicopter gunnery. The Colorado Springs area has a mild year-round climate. In January, the coldest month, temperatures average a high of 43 degrees and a low of 23 degrees with a mean of 33 degrees. August, the warmest month, has an average high of 84 degrees and a low of 61 degrees with a mean of 73 degrees. The area averages 42.4-in. of snow annually.

Fort Carson was established in 1942, following Japan's attack on Pearl Harbor. The city of Colorado Springs purchased land south of the city and donated it to the War Department. Construction began immediately. The first building, the camp headquarters, was completed 31 January 1942. Camp Carson was named in honor of the legendary Army scout, Gen. Christopher "Kit" Carson, who explored much of the West in the 1800s. Facilities were provided for 35,173 enlisted men, 1,818 officers and 592 nurses. Nearly all of the buildings were of the mobilization type construction with wood sided exteriors. During World War II, over 100,000 soldiers trained at Camp Carson. Along with three other infantry divisions—the 71st, 104th and 10th Mountain—more than 125 units were activated at Camp Carson and more than 100 others were transferred to the Mountain post from other installations. Camp Carson was also home to nearly 9,000 axis prisoners of war, mostly Italians and Germans. Colorado was where the Army conducted cold weather and mountain warfare training. Activity at Camp Carson was greatly reduced following the end of World War II. With the onset of the Korean War however, activity once again increased. Many Reserve and National Guard units were called to active duty and stationed at Camp Carson dur-

ing this time. Camp Carson became "Fort Carson" in 1954. In the 1960s, mechanized units were assigned to the Mountain Post. At this time additional training land was purchased, bringing the post to its current size of 140,000 acres. Throughout its history, Fort Carson has been home to nine divisions. An additional training area, comprising 237,000 acres, was purchased in September 1983. Named the "Piñon Canyon Maneuver Site," this training area, located approximately 100 miles to the southeast, is used for large force-on-force maneuver training. For more than five decades, Fort Carson has provided trained and ready soldiers to meet operational requirements.

Fort Carson has a very diverse military and civilian population. Over 15,000 soldiers and 3,100 civilians are assigned to the Mountain Post. The major units assigned to the post include a mechanized infantry brigade, a Special Forces group, an armored cavalry regiment, and an area support group. Many other smaller units also call Fort Carson home. The 7th Infantry Division was reactivated 4 June 1999 at Fort Carson, Environmental stewardship of Fort Carson's natural resources is extremely important. The directorate of Environmental compliance and Management (DECAM) oversees the management of Fort Carson's training areas and conducts unit instruction on maneuver damage prevention. DECAM also has a hazardous waste reaction team that is employed if an environmental emergency arises.

Audit Team and Master Audit Schedule by Team, Location, and Hour

The Fort Carson POA took place over a 5-day period between Monday, 19 May and Friday, 23 May 2003. Table 45 lists of the POA participants. Figure 12 shows this approach to process energy optimization at Fort Carson. Figure 13 shows the master audit schedule.

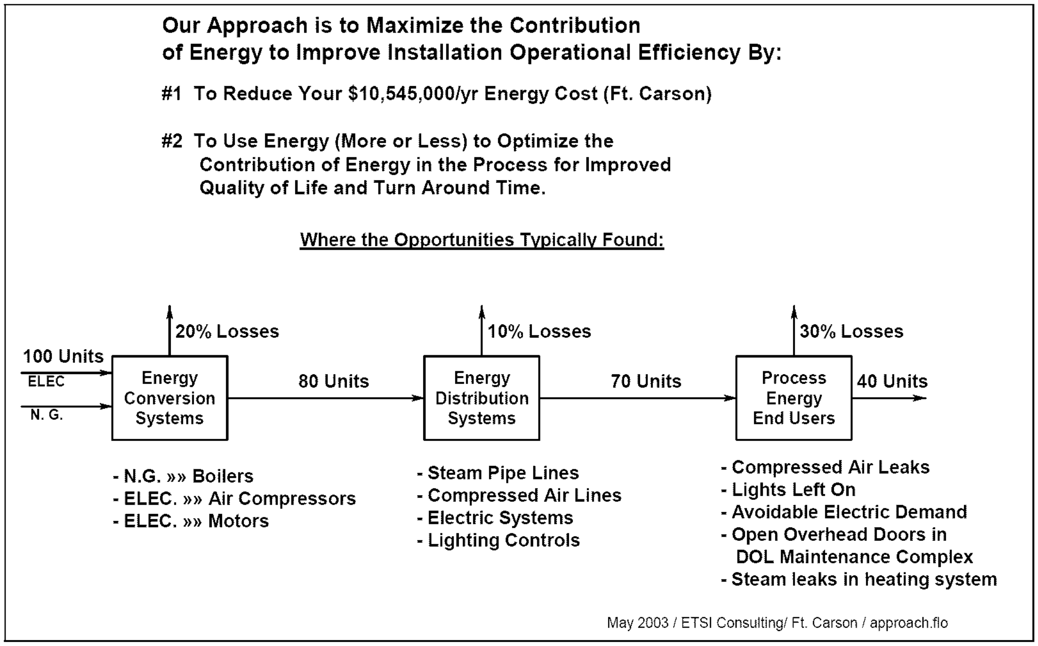


Figure 12. ETSI approach to process energy optimization at Fort Carson.

Table 45. Fort Carson POA participants (19-23 May 2003).

Name	Work Area	Name	Work Area
Mike Argollo	DOL-Maint. Division	John Vavrin	CERL
Jerry Arnett	LB&B HVAC	Mike Lin	CERL
Scott Boulden	DOL-Maint. Division	Tarek Abdalleh	CERL
Bobby Browning	DOL-Log. Man. Division	Roch Ducey	CERL
Frank Brownlee	DOL-Maint. Division	Bill Taylor	CERL
Scott Clark	DECAM	Leonard Thomas	IMA
Jerry Clark	DOL-Maint. Division	Randy Jones	DOE
Alan Davis	DPW	Walt Smith	ETSI
Harry Flanagan	ITT/DOL-Main. Division	Clay Conner	ETSI
Ray Gentilini	ITT/DOL-Main. Division	Bob Erikson	ETSI
Dan Golden	DPW		
Vince Guthrie	DPW		
Mike Hall	DOL-Maint. Division		
Lynn S. Hinton	DPW		
Jefferson C. Hockenberry, Jr.	DECAM		
Allen Jackson	DOL-Log. Man. Division		
Joseph J. Massouda	DOL-Log. Man. Division		
Aulaua Onosai	ITT/DOL-Main. Division		
Paul E. Parker	ITT/DOL-Main. Division		
Bob Reeves, Sr.	LB&B HVAC		
Mack Silversein	DOL-Maint. Division		
Don Simmons	DPW		
Lewis Strickland	DOL-Maint. Division		

Day 1 **Monday, April 21**	Day 2 **Tuesday, April 22**	Day 3 **Wednesday April 23**	Day 4 **Thursday, April 24**	Day 5 **Friday, April 25**
(0630 – 0730) ETSI tour of process	(0630 – 0730) ETSI tour of process	(0630 – 0730) ETSI tour of process	(0630 – 0730) ETSI tour of process	(0630 – 0730) Re-tour any process if needed
(0800 – 0900) Introduction/overview meeting	(0800 – 0830) Summarize Process #1: Heating Plant	(0800 – 0830) Summarize Process #2 Laundry	(0800 – 0830) Summarize Process #3 Paint/Blast	(0800 – 0830) Summarize Process #4 Engine repair/overhaul
(0900 – 1200) Develop OLBs -Base-wide OLBs: electricity natural gas and water/waste water -Process specific OLBs: 1. Heating plant 2. Laundry 3. Paint/blast 4. Engine repair / overhaul	(0830 – 1700) Process #2: Laundry AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% "What Ifs" 3. Develop simplified Block Process Flow Diagram	(0830 – 1700) Process #3: Paint/Blast AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% "What Ifs" 3. Develop simplified Block Process Flow Diagram	(0830 – 1700) Process #4: Engine repair/overahaul AM Session (0830 – 1200) 1. Identify CCIs 2. Develop manufacturing cost structure and 10% "What Ifs" 3. Develop simplified Block Process Flow Diagram	(0830 – 1030) Prepare for Debrief Session (1030 – 1200) Debrief Session
(1200 – 1300) Lunch	(1200 – 1300) Lunch	(1200 – 1300) Lunch	(1200 – 1300) Lunch	1200 - Adjourn
(1300 – 1700) Process #1: Heating Plant 1. Identify CCIs 2. Tour Heating plant 3. Brainstorm PEO solutions 4. Select and group solutions 5. Develop PEO economics	Process #2: Laundry PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select "top" PEO solutions 7. Develop PEO economics	Process #3: Paint/Blast PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select "top" PEO solutions 7. Develop PEO economics	Process #4: Engine repair/overhaul PM Session (1300 – 1700) 5. Brainstorm PEO solutions 6. Select "top" PEO solutions 7. Develop PEO economics	ETSI documentation work begins.
1700 – Adjourn	1700 - Adjourn	1700 - Adjourn	1700 – Adjourn	
OLB: One-Line utility Balance POA: Process Optimization Assessment CCI: Critical Cost Issue PEO: Process Energy Optimization				

Figure 13. Master audit schedule.

The overall success of the POA was due to a high level of involvement, active participation and enthusiasm exhibited by the POA Team. The willingness of Fort Carson team members to identify Critical Cost Issues (CCIs) guided the scope of work and made it possible to get these remarkable results in only 4 days. Without their input and high level of commitment, the consultants would not have been able to independently create these results.

The Master Audit Schedule below shows how the onsite time was organized by team, activity, location and hour. The purpose of the schedule was to provide a framework for the team to follow and make sure that all of the critical areas in the scope of work were covered.

Analysis of Energy Supply, Consumption, and Costs

In fiscal year 2002 (FY02), Fort Carson consumed 131,162,000 kWh with an annual average load of 14,980 kW costing $5,730,000 at 4.37¢/kWh. During the same period, the installation used 956,240 MMBtu of fuels that cost $4,815,000 at an average cost of $5.04/MMBtu. For the entire year Fort Carson spent approximately $10,545,000 for energy.

The post energy systems converted the kWh of electricity and Btus of fuel into various productive utilities such as compressed air, steam, and shaft power to support end uses. These annual purchased energy costs and variable unit costs are used as the cost basis of savings for the economic analysis of Energy Conservation Measures (ECMs).

Table 46 lists a breakdown of purchased electricity and fuel by end user and the cost basis for each.

Table 46. Breakdown of purchased electricity and fuel by end user.

Electricity	k$/yr	% total	Fuel	k$/yr	% total
1. Housing	$998	17.4%	1 Heating plant No. 1860	$1,200	24.9%
2. Barracks – Ben & Blair	$669	11.7%	2. Family housing	$960	19.9%
3. DOIM (IT Center)	$612	10.7%	3. Heating plant No. 6290	$800	16.6%
4. Barracks & motor pool	$594	10.4%	4. Small package boilers	$790	16.4%
5. Hospital	$554	9.7%	5. Miscellaneous	$649	13.5%
6. 8000 area (11 bldgs)	$445	7.8%	6. Heating plant No. 9609	$241	5.0%
7. Army airfield	$297	5.2%	7. Heating system No. 8000	$175	3.6%
8. Sewage Plant /Motor Pool	$297	5.2%	Total	$4,815	100.0%
9. Chiller plant 1861	$230	4.0%	Unit cost basis of savings:		
10. HQ building	$172	3.0%	a.) Electricity@4.37¢/kwh (incl.$6.18/kW-mo)		
11. Commissary	$162	2.8%	b.) Natural gas @$5.03/MMBtu		
12. Office buildings	$134	2.3%	c.) No. 2 FO @ $0.69/gal or $5.31/MMBtu		
13. Combat Tech Center	$130	2.3%	c.) Water @ $1.46/kgal		
14. Heating plant No. 1860	$114	2.0%	d.) Sewer @ $2.84/kgal		
15. Heating plant No. 6290	$111	1.9%			
16. 10th Special Forces	$104	1.8%			
17. Miscellaneous	$61	1.1%			
18. Retail Center	$46	0.8%			
Total	$5,730	100.0%			

Capital Project ECM Highlights

Table 47 shows 19 of the ECMs that require a capital investment, but that have excellent paybacks. The total annual savings for the combined list equals $1,521,300 with an installed capital cost of $1,250,300 and a simple payback of 0.8 years.

Table 47. Capital project ECMs.

ECM	Energy Conservation Measure	Type of Meas.	Net Annual Savings ($k/yr)	Installed Cap. Cost ($k)	Simple PB (yrs)
HP-03	Shut off HW generator between 10 p.m. and 4 a.m. during warm months and lower HW recirculation loop flow with VDF yet maintain system pressure.	CP	$19.40	$2.00	0.1
MC-05	Replace “once thru” CSU cooling water to cool 2 – 75 hp Sullair air compressors with packaged, closed loop system	CP	$11.70	$2.00	0.2
MC-10	Extend exhaust stack on Dynos to eliminate fumes entering intake ventilation	CP	$18.50	$3.20	0.2
HP-09	Install capability to isolate selected areas of the HW distribution system to allow maintenance without shutting entire system down.	CP	$874.00	$400.00	0.5
MC-04	Add shut off controls to Joy air compressors after compressed air leaks are repaired	CP	$1.20	$0.60	0.5
PW-01	Initiate Post-wide control of peak electrical demand by (a) temporary curtailment of non-critical loads with an EMCS (b) load displacement and (c) voluntary turn-off	CP	$70.80	$50.00	0.7
HP-08	Insulate all aboveground bare HW and steam piping for Bldg. 1860 Heating Plant dist. system & end users.	CP	$9.90	$8.00	0.8
PW-08	Insulate and repair leaks on all justifiable steam and HW systems, post-wide underground dist. systems	CP	$79.00	$80.00	1.0
PW-09	Develop long term metering plan to save 2% of elec. cost	CP	$114.60	$120.00	1.0
HP-06	Install a VFD on the combustion air fan motor and control existing continuous O_2 to maximize efficiency over the wide swings in HW demand	CP	$26.3	$17.50	0.7
MC-03	Insulate bare steam valves flanges and fittings	CP	$7.90	$8.00	1.0
MC-09	Replace 10 of 12 roof top units	CP	$120.00	$120.00	1.0
HP-05	Add VFD to 75 hp AC motor on one of the three recirculation pumps	CP	$10.40	$15.00	1.5

ECM	Energy Conservation Measure	Type of Meas.	Net Annual Savings ($k/yr)	Installed Cap. Cost ($k)	Simple PB (yrs)
HP-02	Provide additional steam capability for mess halls and with small direct-fired on demand temperature boost to allow lower HW temperature.	CP	$15.10	$24.00	1.6
MC-06	Repair seals to windows in the 239 office area	CP	$10.80	$17.50	1.6
HP-04	Replace old 75 hp DC motor on recirculation pump with an AC motor and add VFD	CP	$11.70	$22.50	1.9
HP-07	Install “drop-in” economizer in HW generator stack and transfer recovered heat to existing air pre-heater	CP	$40.00	$80.00	2.0
MC-07	Install fast open/close doors on high traffic bays	CP	$26.20	$90.00	3.4
MC-08	Install Solar wall on south side of building 8000	CP	$53.80	$190.0	4.4
			$1,521.3	$1,250.3	0.8

Energy Analysis: Costs

This section provides a summary of cost and usage for electricity, natural gas, liquid propane, and fuel oil. It also shows the detailed calculations that translate these amounts into corresponding values for steam.

Annual Electric Consumption and Costs

During 2002, Fort Carson had an average electric load of 14,980 kW and used 131,162,000 kWh for a total cost of $5,730,000. This cost has two components. The first is the energy cost for the consumption of kWh. The cost for this was $4,330,000, or 75 percent of the total cost. The second component is a demand charge for the highest kW demand in any 15 minute period during each month of the year. The cumulative charge for peak demand for 2002 was based on the summation of monthly charges for peak demand each month. The cost for this charge was $1,400,000 or about 25 percent of the total cost.

Annual Fuel~~s~~ Consumption and Cost

Table 48 summarizes the amounts of natural gas, liquid propane, and No. 2 fuel oil used at Fort Carson during 2002.

Table 48. Fort Carson use of natural gas and No. 2 fuel oil in 2002.

Fuel type	FY02 Usage (MMBtu)	FY02 Annual Cost ($)
Natural Gas (NG)	950,400	$4,784,000
No. 2 Fuel Oil (FO)	5,840	$31,000
Total	956,240	$4,815,000

Unit Cost Calculations and Cost Basis of Savings (CBoS)

Since specific energy conservation measures are focused on some type of end use utility like compressed air, shaft power, lighting, etc. to support a process, the team needed a method to translate reduced consumption at the end use back to lower electricity usage or lower fuel consumption and the associated cost savings. As a result, researchers provided the team with translation formulas that convert incremental end use consumption back to the energy source and ultimately back to dollar cost. This is called the "Cost Basis of Savings" (CBoS). Table 49 lists the cost values for an incremental unit of a utility and the underlying equation that derives this amount. The PET may continue to use this table for future ECMs. Since the formulas are shown, the CBoS may be modified based on changes in operating assumptions.

Table 49. Cost basis of savings (CBoS).

Utility or cost factor	Derivation and Cost
1. Electricity	$0.0437/kWh including both energy and demand. Energy cost = $0.033/kWh for energy Demand charge = $5.90/kW-month = $383/kW-year (combined energy and demand) = 1 kW used for 8,760 hrs/yr = $71/kW-year (demand only)
2. Horsepower	1 hp x 0.746 kW/Hp x 8760 hrs/yr x $0.0437/kWh = $285/hp-yr
3. Natural Gas	$5.03/MMBtu Monthly range from $3.75 to $5.83/MMBtu
4. No. 2 Fuel Oil	$0.69/gal 1,000,000Btu/130,000Btu/gal No. 2 F.O. x $0.69/gal No. 2 F.O. = $5.31/MMBtu
6. Hot Water	$5.03/MMBtu NG/75% HW Generator Efficiency = $6.71/MMBtu
7. Water and Sewer	Water = $1,412,911/yr/962,366 kgal (incl. family housing) = $1.46/kgal Sewer = $1,476,333/yr/519,320 kgal (REEP data) = $2.84/kgal

Links Between Electricity and Environmental Emissions

Electricity: Basis for 1,000 kWh (1 MWh)

Energy Analysis: Patterns of Electricity Use

This Chapter analyzes hourly electric load data over different intervals of time at Fort Carson. Through Colorado Springs Utilities (CSU), Fort Carson provided interval data for the period May 2002 to April 2003. Researchers examined this data, posed questions that will require further investigation, and drew some conclusions that may be helpful in guiding the Fort Carson PET toward more productive energy management strategies.

Electric Generation Assumption for the Western United States

This work assumed that, in Colorado, most electric generation in the region is coal fired at an average heat rate of 11,000 Btu/kWh.

Emission Assumptions for Western United States

1,000 kWh (coal-fired) = 2,170 lb CO_2 or 1.085 tons

1,000 kWh (coal fired) = 4.5 lb NO_x

1,000 kWh (coal fired) = 24.5 lb SO_2

Load Profiles and Load Duration Curves

Load profiles and load duration curves are tools that energy managers use to uncover usage trends and patterns and opportunities for energy savings. The load profiles shown in Figures 14 to 21 illustrate the following discussion.

Typical Weekly Load Profiles by Season

The weekly load profiles show 168-hour chronological graphs of load data that go from Monday to Sunday during different weather and/or business operating seasons. They typically vary because of the influences of weather and seasonal production cycles.

Figures 14 through 17 show the typical weekly load profiles by seasonal time of year for Fort Carson. The weeks that were selected vary by time of year and attempt to isolate an event that occurred where possible. Since there were a few different peculiar events that were picked up in the data, the graphs demonstrate how the PET may isolate an event and analyze what may have happened.

The weekly load profile for the week of 27 January through 2 February 2002 (Figure 14) shows a normal operation with the exception of a demand spike of a 4+MW that occurred over a period that lasted for a few hours. Further investigation by the POA Team and CSU discovered that it was a false peak caused by load switching at the substation. As a result of finding this data problem, CSU refunded Fort Carson approximately $16,000. (ECM PW-02 gives more details.) This illustrates the importance of periodically reviewing electrical interval data in a graphical format.

The weekly load profile for the week of 20-26 May 2002 (Figure 15) shows a typical weekly profile for the springtime with the exception of a significant drop in demand in the early morning hours of Wednesday, 22 May. This may have been an outage or it could have been a substation going offline or some other significant event.

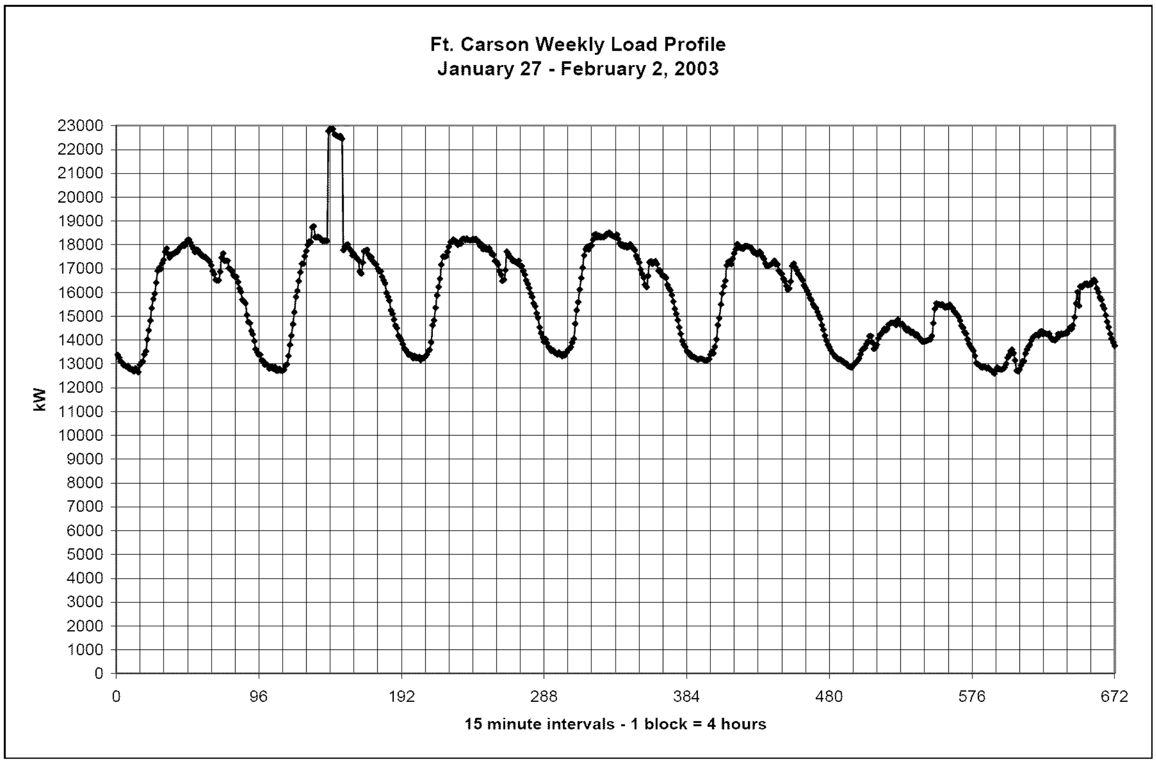


Figure 14. False event in January 2003.

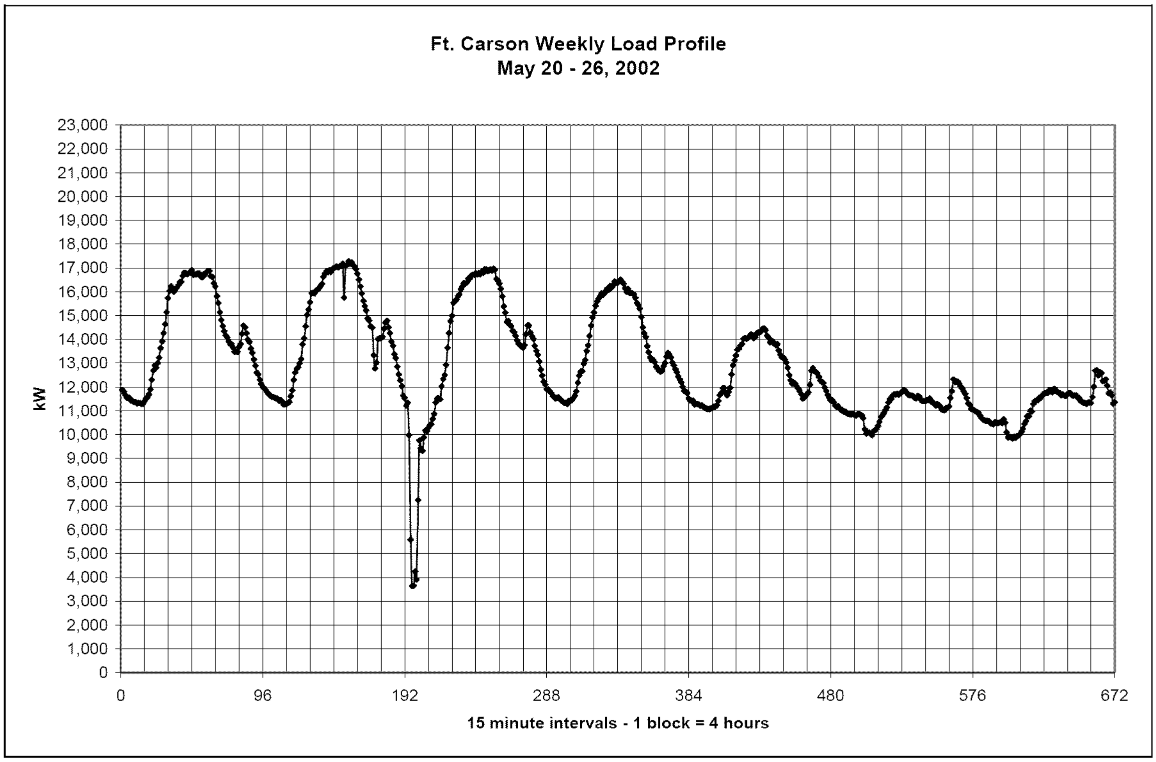


Figure 15. Extreme low in May 2002.

The weekly load profile for 5-11 August 2002 (Figure 16) shows the legitimate peak for the entire 12-month period with the anomaly in January taken out of consideration. This is when the expected annual peak would occur.

The weekly load profile for 4-10 November 2002 (Figure 17) shows a typical weekly profile for the fall with the exception of a significant drop in demand in the early morning hours of Friday, 8 November. This may have been an outage or it could have been a substation going offline or some other significant event.

Questions for PET

1. What could be done in family housing and the barracks to control peak demand in the summer? (Figure 14)
2. What is the biggest driver in electrical demand between the highest and lowest periods of the year? Is it weather, post population, significant operational activity or some combination of drivers?
3. What exactly happened in May and November that caused the load to drop so dramatically?
4. If the events in May and November were outages, were there significant costs that resulted from these occurrences?

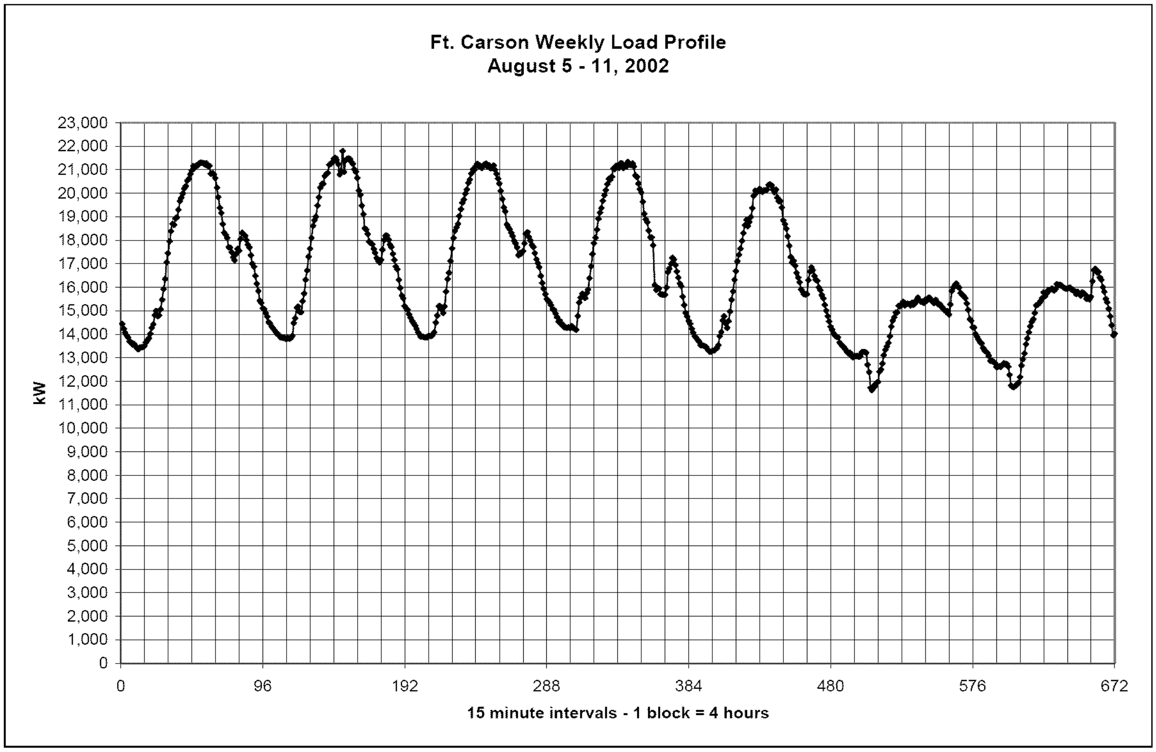


Figure 16. Weekly load profile: typical summer peak in August.

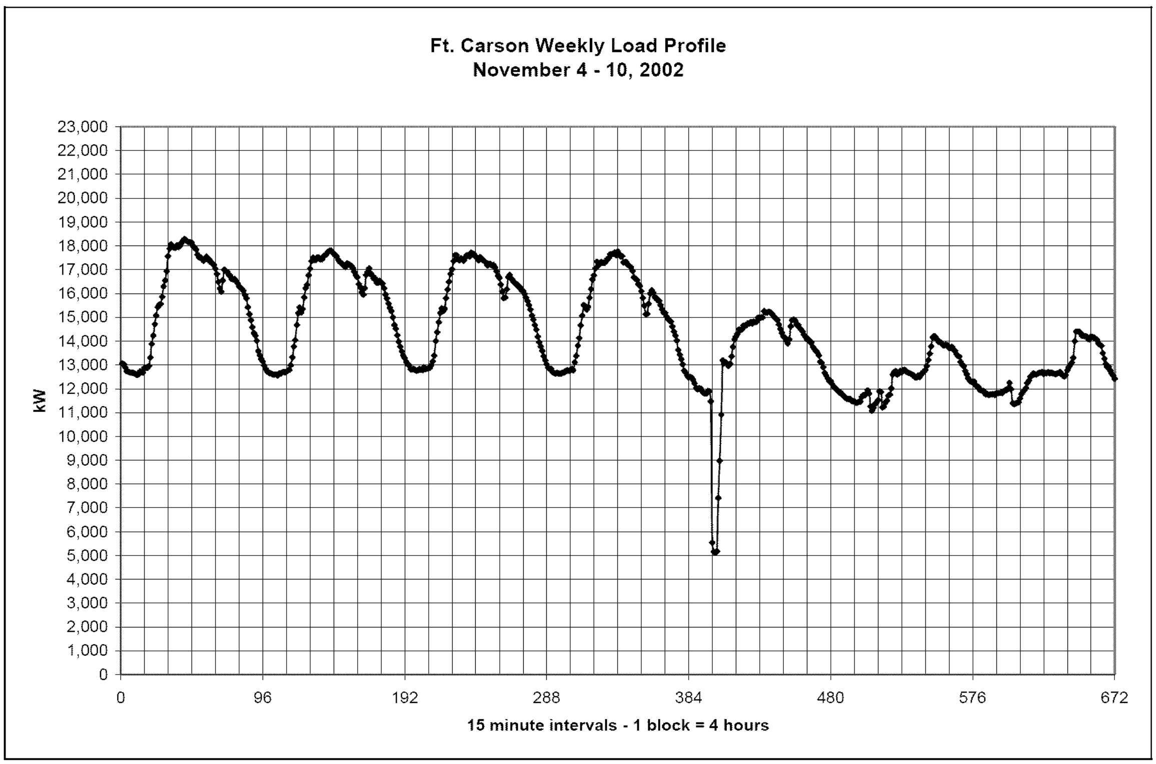


Figure 17. Weekly load profile: extreme low in November.

Annual Chronological Load Profile

The annual chronological load profile is a graph of the electrical load levels shown sequentially over the 8,760 hrs of the year. This view shows variability in usage from hour to hour, day to day, and month to month. Figure 18 shows the annual chronological load profile for Fort Carson. This graph reveals how the load varies from about 10,000 kW in May to almost 22,000 kW during August 2003. This excludes the January 2003 event that turned out to be erroneous and four events where the load dropped to between 4,000 kW and 8,000 kW for very short periods.

Question for the PET

The night-time, weekend and holiday demand goes between 12,000 kW and 18,000 kW during non-summer months. Are all of these loads, particularly HVAC loads motor loads during the fall and spring justified? A reduction of 1,000 kW of load for nights and weekends (60 percent of the week) for during spring and fall (50 percent of the year) is equal to about $86,700 ($0.033/kWh – energy only x 8760 hrs/yr x 60% (weeknights and weekends) x 50% (spring and fall x 1,000 kW).

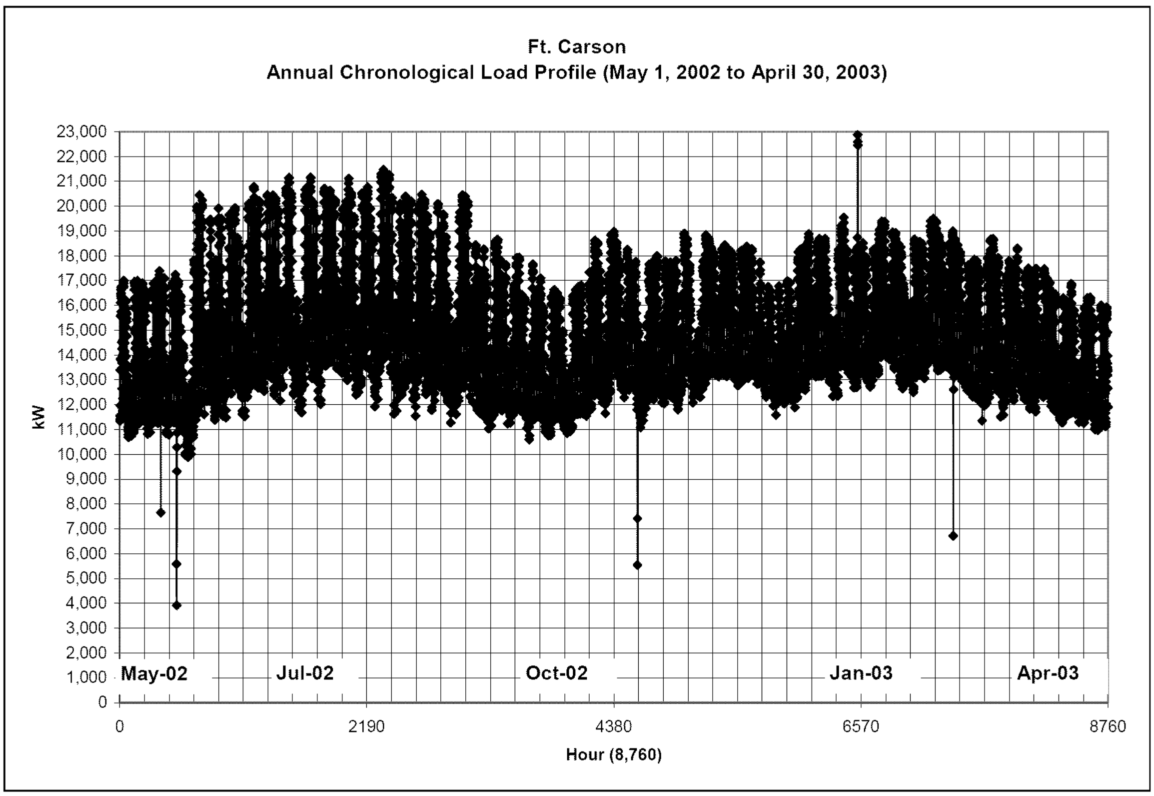


Figure 18. Annual chronological load profile.

Example Load Duration Curve

A load duration curve is derived from re-ordering a number of hours of load data recorded over a chronological period from the highest load observed to the lowest load observed. This curve provides unique insight into the levels of energy usage throughout a given period of time. The area under the curve represents the total kWh usage during the period. It is especially useful in evaluating peak shaving opportunities.

At Fort Carson, the CSU calculates the peak demand charge each month for the peak periods. For the winter months, October through March, the peak periods are Monday through Friday from 4 p.m. to 10 p.m. For the summer months, April through September, the peak periods are (Monday through Friday from 11 a.m. to 6 p.m.). Many other utilities base the peak demand on any event that occurs during the peak period of the year for the entire year. This penalizes all of the other months of the year based on a peak that may have occurred during one hour in the year. Therefore, it is possible to peak shave as frequently or as little as the PET wants. If it is inconvenient to peak shave in 1 month, it is still possible to save on peak demand charges the very next month.

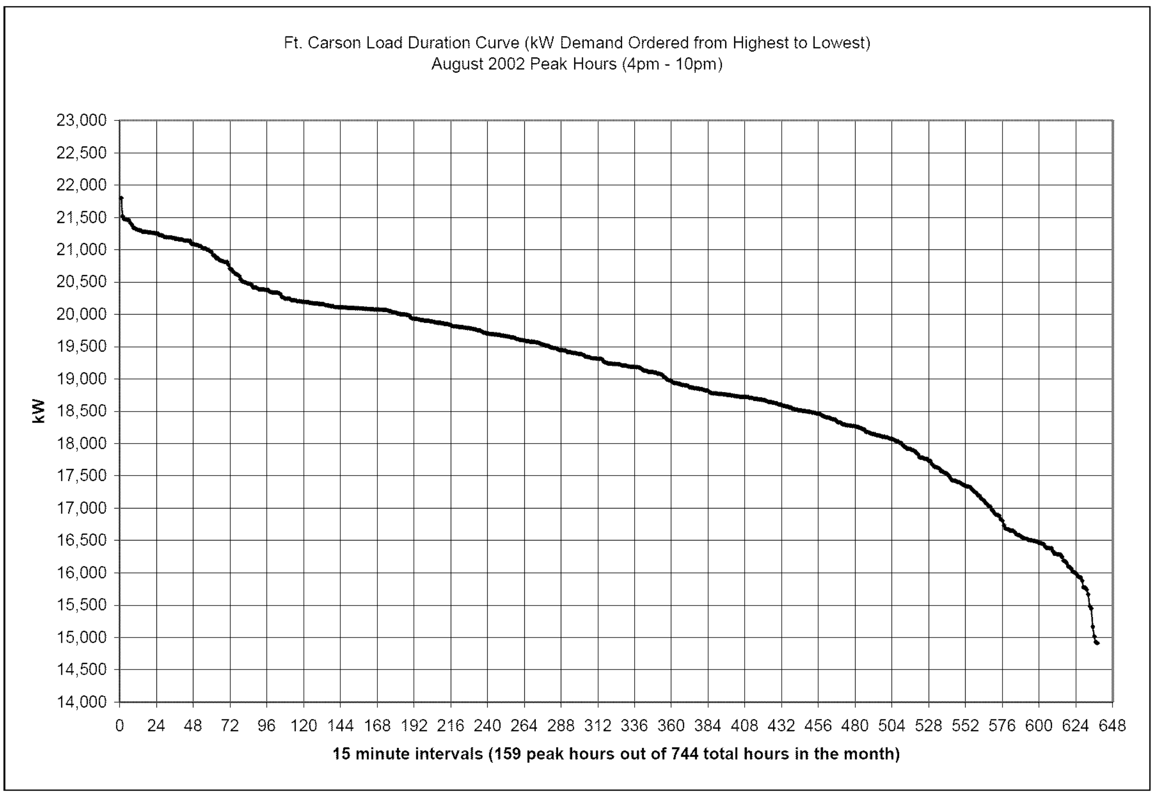


Figure 19. Example monthly load duration curve (August 2002).

Figure 19 shows a monthly load duration curve (including only the peak hours) for August 2002. Figure 19 also shows the annual load duration curve for Fort Carson. The highest demand observed on a monthly basis is in August (excluding the anomaly in January 2003). Fort Carson can save on peak demand every month. Therefore, the PET can follow this template to do a load duration curve for each month of the year. This will help identify those months with the greatest opportunity for load shedding without affecting the installation morale, comfort, or safety. (ECM PW-01 [p 27] details this concept.)

Energy Sub-Metering for Plant Utilities

Even though the site-wide electrical hourly energy data is very helpful, it does not provide insight into the hourly energy usage by electrical system or end use. It is critical to obtain sub-metered data that gives this level of detail. To effectively manage energy, it must be measured at a level that is controllable.

Fort Carson sub-meters by substation. While this helps to achieve a better level of detail, it still does not enable the PET to really understand areas where the load could be controlled more effectively. To develop and monitor effective ECMs, the PET needs to sub-meter data on more points and to monitor the results from implemented ECMs (see ECM PW-09, p 111)

No Cost and Low Cost ECM Highlights

The economic analyses of the ECM results appear to be outstanding. Table 50 highlights nine ECMs that can be implemented at no or low cost. The total annual savings for these is $1,301,700

Table 50. No cost and low cost ECMs.

ECM	Energy Conservation Measure	Type of Meas.	Net Annual Savings ($k/yr)	Installed Cap. Cost ($k)	Simple PB (yrs)
PW-03	Use the lowest cost fuel based on the cost of current NG supply and FO inventory costs	SD	$542.10	$0.00	Immed.
PW-10	Promote “old fashioned” energy conservation to reduce fuel and kWh by turning off unnecessary loads	LU	$422.00	$0.00	Immed.
PW-04	“Group” re-lamp versus “spot” re-lamp, 70% of 12 million sq ft	LU	$275.10	$0.00	Immed.
HP-01	Optimize HW loop temperature at lower levels to meet seasonal and troop occupancy requirements. Control HW return temperature rather than holding HW supply temperature constant at 355°F	SD	$15.10	$0.00	Immed.

ECM	Energy Conservation Measure	Type of Meas.	Net Annual Savings ($k/yr)	Installed Cap. Cost ($k)	Simple PB (yrs)
PW-05	Implement a compressed air (CA) leak reduction program to reduce CA consumption	LU	$15.00	$0.00	Immed.
MC-02	Survey and fix 30% of 100 steam traps	LU	$10.00	$0.00	Immed.
PW-06	Reduce 80% of all compressor pressure set point by 20 psig to reduce motor load by 10%	SD	$6.90	$0.00	Immed.
PW-07	Replace standard V-belts with COG type V-belts to save 1.5% of motor load	LU	$6.40	$0.00	Immed.
PW-02	Graphically review electrical interval data from CSU each quarter to identify potential meter/billing errors	LU	$4.90	$0.00	Immed
MC-01	Determine which boiler has the highest efficiency and operate it for most of the annual hours	SD	$4.20	$0.00	Immed.
			$1,301.70	$0.00	

Energy Analysis: Energy Systems and End Users

One Line Balances (OLBs)

This section provides unique representations of the utility systems called OLBs. The OLB is a diagram that accounts for all of a plant utility flow and annual cost from the source to the major end users. OLBs are meant to be simple and approximate, not precise or necessarily 100 percent complete. The primary purpose of an OLB is to obtain a total energy picture of the installation that will:

1. Stimulate the POA Team to identify more and better ECMs
2. Provide a basis from which the recommended measures can be technically and economically quantified.

The OLB for Fort Carson electricity (Figure 20) shows the installation's 14,980 kW (annual average load), totaling 131,162 MWh/yr at an annual cost of $5,730,000 and the consumption and cost to all major plant energy systems and departments. The OLB for Electricity estimates the approximate kW flows through the post distribution systems by voltage levels to all major users.

The OLB for Fort Carson Fuel (Figure 21) shows the post's 956,240 MMBtu per year at an annual cost of $4,815,000 and the consumption and cost to all major plant energy systems and departments.

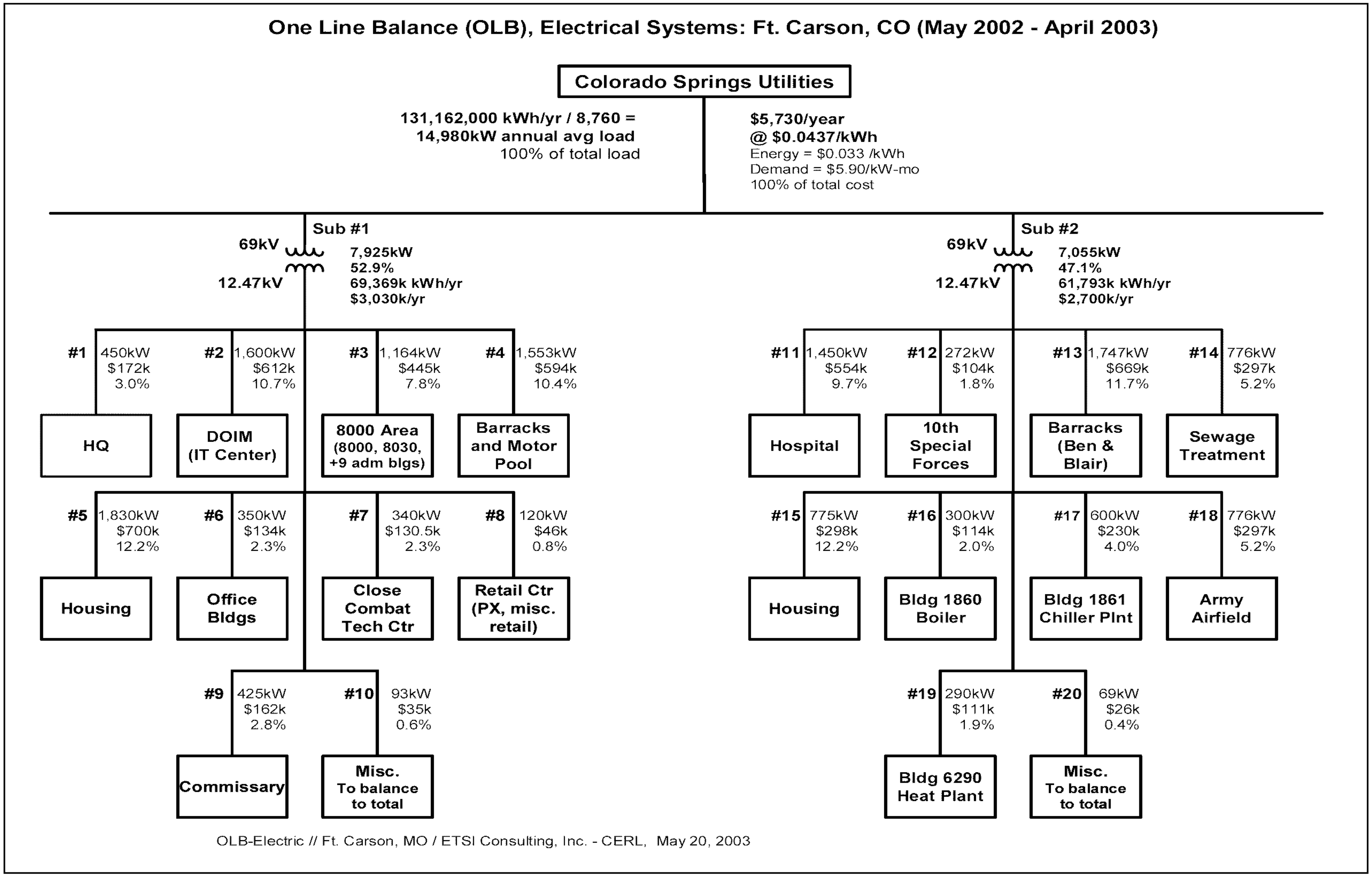


Figure 20. OLB for electrical supply, distribution, and major users.

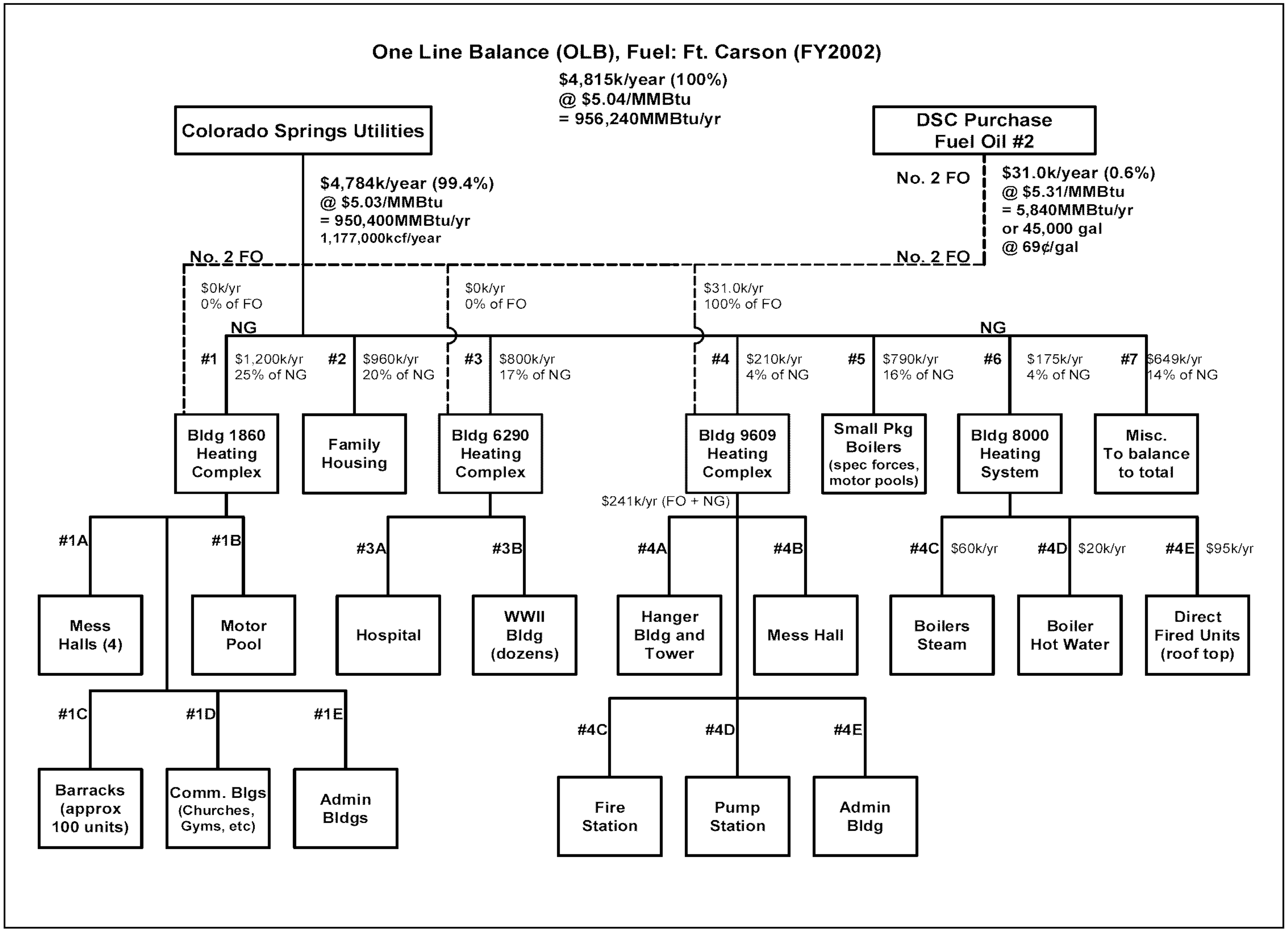


Figure 21. OLB for fuel supply, distribution, and major users.

OLBs provide many benefits to the Audit and analysis. Six of these benefits are:

1. They account for energy at the point of use and create an immediate overall understanding of energy use.
2. They help the team prioritize efforts and saving time by working on the energy systems that consume the most dollars, which represent the greatest financial opportunities.
3. They provide a structured method to quickly stimulate the team to consider ECMs throughout the plant energy systems.
4. They assist in calculating the savings values of ECMs and groups of ECMs.
5. They provide a realistic basis to allocate energy costs to plant areas and business units even without sub-meters.
6. They can be used as a powerful communication tool to explain energy use and costs to plant management and adds credibility to the PET efforts.

Process Optimization Assessment Results

During the onsite period from 19-23 May the POA team examined two primary process areas that included:

1. Building 1860 heating plant
2. DOL Maintenance Complex with special emphasis on the vehicle repair shop and paint/blast.

Using this approach to process optimization the team both technically and financially analyzed the each process and uncovered critical cost issues specific to each area. Then the team collectively identified solutions to the most costly problems. This section of the report shows the following

1. Summary results in table format
2. Critical cost issues that were identified
3. The manufacturing cost structure (where appropriate) and resulting value of process improvements related to improving TAT, labor productivity, decreasing scrap and waste and using energy more efficiently
4. Detailed results in 1-page to 2-page format.

The summary matrices for each process area show the following information by energy system:

1. *ECM Number and Title*. This is a unique number and title that may be referred to in the text of the document
2. *Annual Savings*: this is the savings calculation formula that is derived from the Data Used for Economics. For projects that are paid for with expense money, this result is shown as net of “expense” dollars that are required to implement.

3. *Installed Cost*: this is derived from the Data Used for Economics and is the cost calculation for any "capitalized" dollars that must be expended to fund the project.
4. *Simple Payback*: The simple payback is calculated by dividing the capital cost by the "net savings" and is expressed in years. For projects that do not require capital investment, the payback is immediate.

The one page discussion of each ECM includes:

1. *ECM Number and Title*. This unique number and title may be referred to in the text of the document
2. *Background*. This provides information about the target location in the plant and a statement of fact about the current situation.
3. *Descriptive Scope*. This describes the specific action that will be completed to implement the ECM. It answers the questions what to do, how to do it, where to do it, and when to do it. For example, "install (how?) VFD on 10 hp compressor fan (what?) in heating plant No. 2351 Care (where?).
4. *Data Used for Economics*. This provides any relevant data that may be used as an input assumption into the calculation of costs and savings for the ECM. It generally includes operating and specification data related to the equipment that will be modified, reduction data that quantifies the use and energy reduction of the equipment, and cost data related to material, labor, and other expenses associated with making the recommended changes
5. *Savings Calculation*. This is the savings calculation formula that is derived from the Data Used for Economics. For projects that are paid for with expense money, this result is shown as net of "expense" dollars that are required to implement.
6. *Cost Estimate Calculation*. This is derived from the Data Used for Economics and is the cost calculation for any "capitalized" dollars that must be expended to fund the project.
7. *ECM Summary*. This is a table that shows the financial savings and simple payback and the energy and environmental savings. The simple payback is calculated by dividing the capital cost by the "net savings" and is expressed in years. For projects that do not require capital investment, the payback is immediate.

9 Fort Carson Post-Wide Results

This Chapter is dedicated to ECMs that came out of the POA that are not necessarily specific to any one area of the installation.

Object Statement. Identify ECM solutions that will optimize energy cost post-wide (higher efficiency, lower consumption) at equal or better TAT, quality of life, safety, or morale (Table 51).

Table 51. Post-wide (PW) ECMs.

ECM	Energy Conservation Measure Descriptive scope: what, where, why	Type of measure	Net Annual Savings ($k/yr)	Installed Capital Cost ($k)	Simple Payback (yrs)
PW-01	Initiate Post-wide control of peak electrical demand by (a) temporary curtailment of non-critical loads with an EMCS (b) load displacement and (c) voluntary turn-off	CP	$70.8	$50.0	0.7
PW-02	Graphically review electrical interval data from CSU each quarter to identify potential meter/billing errors	LU	$4.9	$0.0	Immed
PW-03	Use the lowest cost fuel based on the cost of current NG supply and FO inventory costs	SD	$542.1	$0.0	Immed.
PW-04	"Group" re-lamp versus "spot" re-lamp, 7.8 million sq ft	LU	$275.1	$0.0	Immed.
PW-05	Implement a compressed air (CA) leak reduction program to reduce CA consumption	LU	$15.0	$0.0	Immed.
PW-06	Reduce 80% of all compressor pressure set point by 20 psig to reduce motor load by 10%	SD	$6.9	$0.0	Immed.
PW-07	Replace standard V-belts with COG type V-belts to save 1.5% of motor load	LU	$6.4	$0.0	Immed.
PW-08	Insulate and repair leaks on all justifiable steam and HW systems, post-wide underground distribution systems	CP	$79.0	$80.0	1.0
PW-09	Develop long term metering plan to save 2% of electricity cost	CP	$114.6	$120.0	1.0
PW-10	Promote "old fashioned" energy conservation to reduce fuel and kWh by turning off unnecessary loads	SD	$422.0	$0.0	Immed.
	Total		$1,536.8	$250.0	0.2

Abbreviations: ECM area and Categories

PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost); LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical; PET = follow up by the PET

Critical Cost Issues – Post wide

Task: Identify CCIs that apply to Post-wide problems that if solved will save $$ and improve the end user operations

CCIs = problems or opportunities that waste a significant amount of $$

Facility/Installation-Wide

Utility Control System (UCS) works really well in those areas where it is continuously monitoring, controlling, and managing energy use but it is underused.

The facility-wide demand costs $1.4M/yr and the peak demand (kW) can be reduced by 600 to 1000 kW through demand control either by shedding non-critical loads or displacing loads where there is an emergency engine generator set.

There is no comprehensive compressed air leak reduction program in place.

Most belt driven motors are currently using standard V-belts as opposed to energy-saving COG-type belts.

There is no comprehensive plan in place to sub-meter electricity or fuel to more effectively manage consumption. If you do not meter it, you cannot manage it.

The high temperature hot water distribution system is in the process of being replaced, but there are still a variety of places where bare pipe is uninsulated.

There is no comprehensive energy conservation plan in place.

ECM PW-01

Facility: Fort Carson
Area: Post-wide
Description: Initiate post-wide electrical peak demand control to reduce purchased electrical cost.

Background

From May 2002 to April 2003 Fort Carson paid approximately $1,400,000 in electrical demand charges. This represents about 25 percent of the total

$5,730,000 electric cost. The demand charge is calculated on a monthly basis at $5.90/kW-month based on the peak monthly demand during the peak hours defined Colorado Springs Utilities (CSU), the electric supplier to the installation. The primary advantage is that the peak demand is based on the actual peak in a given month. Many other electric utilities calculate it based on the highest recorded observation in a 12-month period. This means an electric user can be penalized for an entire year based on just one 15- or 30-minute period.

With a monthly demand charge, the demand must be actively controlled on a monthly basis to achieve maximum savings for the year. However, if it is not convenient or possible to control load in a particular month, it is always possible to capture savings in the following month. One of the best methods available to control demand in this situation is an Energy Management Control System (EMCS). By tying an EMCS to the largest non-critical loads it may be possible to achieve peak load reductions without affecting the morale, comfort, and safety of base personnel.

Based on 2002, 15-minute electric load data, Fort Carson could have easily shaved at least 1MW off of the peak load with only about 250 hrs of demand control on annual basis (less than 3 percent of the hours of the year). The value of this 1MW peak reduction would have been about $70,000 and could have been accomplished in a variety of ways. If the load in 2002 is any indication of the future, one would anticipate similar results.

Descriptive Scope

Implement a peak demand reduction program to lower peak demand by at least 1MW. There are at least four methods available to accomplish this goal.

Use existing or upgraded Energy Management Control System (EMCS) to control a limited number of loads that total 2 MW as the base approaches new peak load levels.

Use 2 MW of existing standby generators to shed loads as the base approaches new peak load levels.

Purchase a 2 MW diesel backup generator, tie it to the grid using parallel switchgear and dispatch as the base approaches new peak load levels (usage would fall well within operating constraints).

Encourage energy conservation during peak periods among base personnel.

Data Used for Economics

- Assume EMCS could be installed at \$2,000/point x 20 points + \$10,000 for software
- Assume a total of 10 existing generators would need to be manually turned on 20 times per year @ \$500 per event for labor cost (\$50/generator x 10 generators) = \$10,000/yr in labor cost
- Assume a 2 MW diesel generator with parallel switchgear could be purchased and installed for \$500,000 (\$250/kW).
- Assume that encouraging energy conservation among the troops could be incorporated into existing training programs at no cost.

Savings Calculation

Annual \$ savings =

1,000 kW x \$5.90/kW-month x 12 months = \$70,800/yr savings

Cost Estimate Calculations

Total Cost =

Assumed ECMS solution: (20 points x \$2,000/point) + \$10,000 (computer software) = \$50,000 installed

Table 52 summarizes the benefits of implementing ECM PW-01.

Table 52. ECM PW-01 and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings (\$/yr)	\$70.8K
Capital Cost (\$)	\$50.0K
Simple Payback (years)	0.7
Comments	Capital project

Status/Recommendations for Further Work

The PET should contact various EMCS vendors and encourage a bidding process to develop a plan for peak reduction using and EMCS system. Many vendors may be interested in doing a test project to accomplish a 1MW reduction based on the possibility of a larger project to monitor and control loads throughout the installation. Vendors that may be interested in this work include Honeywell, Siemens, Johnson Controls, and Control Systems International.

ECM PW-02

Facility: Fort Carson
Area: Post-wide
Description: Graphically review electrical interval data from CSU each quarter to identify potential meter/billing errors.

Background

During the Process Optimization Assessment (POA) at Fort Carson in May 2003, the POA team collected electrical interval data from Colorado Springs Utilities (CSU) in an easy to import electronic format. A member of the team spent about 4 hrs manipulating and graphing the data in an Excel spreadsheet. This analysis revealed an electrical peak in January 2003 that looked like an anomaly. It was the highest observation over a 12-month period from May 2002 to April 2003. Since Fort Carson typically has its highest peak loads in the summertime, this 2,700 kW spike in demand over a 4-hr period looked odd. After some investigation internally with Fort Carson energy management staff and CSU, the team learned that it was a load switching event at one of the sub-stations that generated this data. Since it was an error, CSU credited Fort Carson's for approximately $16,000.

If no one had reviewed this data, it is likely that the metering/billing error would have gone un-noticed. Quickly spotting errors like this is one of the many values of reviewing interval data. By spending a few hours each quarter of the year reviewing this data, it may be possible to duplicate this type of savings every few years. Therefore, the PET should incorporate this activity into its Strategic Energy Plan (SEP).

Descriptive Scope

A member of the PET will spend 4 hrs every 3 months graphically reviewing electrical interval data from Colorado Springs Utilities (CSU) as a method of auditing the meter and billing data.

Data Used for Economics

- Assume hourly rate of PET team member is $30/hr (fully loaded).
- Assume it takes 4 hrs per quarter (16 hrs /yr) to review the interval data.
- Assume that the type of savings discovered during the POA ($16,000 billing credit) is found on average every 3 years.

Savings Calculation

Net Annual $ savings =

$16,000 (billing credit)/3 years – [16 hrs (time spent per year by PET team member) x $30/hr (fully loaded hourly rate)] = $5,330 - $480 = $4,850/yr

Cost Estimate Calculations

Total Cost =

Assume no capital cost. Annual labor cost is assumed in the net annual savings calculation

Table 53 summarizes the benefits of implementing ECM PW-02.

Table 53. ECM PW-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$4.9K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay Up

Status/Recommendations for Further Work

None

ECM PW-03

Facility: Fort Carson

Area: Three of four Heating plants (not Bldg. 8000 Maint. Complex)

Description: Optimize the use of the lowest cost boiler fuel.

Background

As a general practice, it is recommended that any industrial facility that has dual fuel burning capability always burn the lowest cost fuel. Fort Carson has three heating plants with boilers that produce hot water and also have the capability to burn natural gas or No. 2 fuel oil. Many military installations have the good fortune of relatively stable, low cost supplies of No. 2 fuel oil and significant storage capability. At Fort Carson, there is approximately 400,000 gallons of storage capacity and the average price for No. 2 fuel oil has been and may continue to be about $0.69/gal. Based on a Btu value of 130,000Btu/gallon, $0.69/gallon converts to $5.31/MMBtu. Therefore, it stands to reason, that if the

price of natural gas, a much more price-volatile fuel, exceeds $5.31/MMBtu, Fort Carson should burn No. 2 fuel oil.

During FY02, Fort Carson paid an average price of $5.03/MMBtu for natural gas. However, the price varied monthly from a low of $3.25/MMBtu up to a high of $5.84/MMBtu. This means that, in any give month, there is an opportunity to burn No. 2 fuel oil and cap the maximum paid for fuel at $5.31/MMBtu. Since natural gas prices are expected to be even higher this coming year, this concept is even more relevant.

Descriptive Scope

Use No. 2 FO in three boiler systems whenever the price is significantly advantageous. The purpose of this ECM analysis is to clearly show the economic significance of the current practice of maximizing the use of the lowest cost fuel.

Data Used for Economics

Table 54 shows FY02 natural gas usage in MMBtu against the current forward price curve (6-17-03) for natural gas as traded on NYMEX and monthly savings that hypothetically would be saved by using No. 2 fuel oil when the price for natural gas is above $5.31/MMBtu.

Table 54. FY02 natural gas usage in MMBtu.

Forward Contract Month	Natural Gas Usage Based on FY02 Actual (MMBtu)	Forward Contract Price ($/MMBtu)	Total Cost ($)	Adjusted unit cost using No. 2 FO ($/MMBtu)	Possible $ savings using No.2 FO when NG price > $5.31/MMBtu	Total Cost with savings ($)
Oct-03	65,565	$5.810	$380,931	$5.310	$32,782	$348,149
Nov-03	98,005	$5.970	$585,087	$5.310	$64,683	$520,404
Dec-03	139,021	$6.115	$850,114	$5.310	$111,912	$738,202
Jan-04	149,774	$6.220	$931,591	$5.310	$136,294	$795,298
Feb-04	131,406	$6.150	$808,148	$5.310	$110,381	$697,767
Mar-04	130,387	$5.970	$778,410	$5.310	$86,055	$692,355
Apr-04	75,395	$5.247	$395,596	$5.247	$0	$395,596
May-04	53,679	$5.100	$273,764	$5.100	$0	$273,764
Jun-04	27,626	$5.102	$140,948	$5.102	$0	$140,948
Jul-04	23,591	$5.092	$120,126	$5.092	$0	$120,126
Aug-04	25,484	$5.102	$130,021	$5.102	$0	$130,021
Sep-04	30,459	$5.087	$154,943	$5.087	$0	$154,943
Totals	950,391	$5.839	$5,549,679	$5.269	$542,108	$5,007,572

Savings Calculation

Annual $ savings =

Total savings = Σ (anticipated monthly savings) = $542,108

Cost Estimate Calculations

Total Cost =

No capital or expense costs are required.

Table 55 summarizes the benefits of implementing ECM PW-03.

Table 55. ECM PW-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$542.1K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam Dunk

Status/Recommendations for Further Work

The PET should determine what Fort Carson's decision will be on this recommendation.

ECM PW-04

Facility: Fort Carson
Area: Post-wide (excluding family housing)
Description: "Group" re-lamp rather than "spot" re-lamp the 7.8 mil sq ft of post wide buildings.

Background

The post lighting systems are very efficient due to significant upgrades to the T8 fluorescent lamps with electronic ballasts. However, it was concluded the 90 percent of the posts re-lamping is implemented on a spot basis as the individual or small groups of lamps fail. This is very labor intensive and disruptive to personnel in the facility areas. A far more efficient approach is to "Group" re-lamp all fixtures in a large area or total building at once based on hours of lamp life (typically 20,000 hrs/lamp).

Descriptive Scope

"Group" rather than "spot" re-lamp all fixtures at preset intervals using inexpensive, outside contractor labor.

Data Used for Economics

- Large building sq ft = 7,857,168 sq ft (Fort Carson 2001 Status PowerPoint slides).
- Lighting levels are 0.7 watt/sq ft for an average of 4,000 hrs/yr
- Lighting load is 7.86 mil sq ft x 0.7 watt/sq ft = 5,502 kW (~30% of average kWh, 15% of peak kWh)
- The average multi-lamp fixture 100 watts for a total fixture count of 5,502 kW/0.100 kW = 55,020 fixtures.
- The labor cost to "spot" re-lamp a fixture, one or several at a time, is $30/fixture.
- The cost to "group" re-lamp hundreds of fixtures every 5 years is $5/fixture.

Savings Calculation

Labor, not energy savings from "group" re-lamping =

55,020 fixtures (excluding family housing) x ($30-$5) = $1,375,000 over 5 years.

Annual average savings = $1,375,000/5 years or $275,100/yr.

Cost Estimate Calculations

There are no capital costs associated with this ECM. The savings are in labor costs.

Table 56 summarizes the benefits of implementing ECM PW-04.

Table 56. ECM PW-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$275.1K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay Up

Status/Recommendations for Further Work

Contract out the specific tasks of re-lamping on a "Group" re-lamp concept rather than "spot" re-lamping. There are many other side-benefits of "group" re-lamping including: ladder safety issues, less interruptions of office/building per-

sonnel (do on weekends, etc.), better overall, average lighting systems effectiveness and an automatic, self-sustaining program

ECM PW-05

Facility: Fort Carson

Area: Post wide air compressors

Description: Initiate an annual compressed air leak reduction program.

Background:

The typical industrial facility wastes between 15 to 50 percent of its annual compressed air (CA) production. Industrial facilities generally produce CA from relatively few, large central air compressors. Fort Carson is not the typical industrial facility in that the Post-wide CA systems consist of a very large number of relatively small, individual, de-centralized units located in most of the Post's 40+ buildings.

A very recent compressed air study by FEMP, estimated that Fort Carson has hundreds of air compressors ranging from 1 to 100 hp, Post-wide (See Appendix B, by Frank Moskowitz FEMP contractor, phone No.: 480 563-0107). A list of the largest units (5 to 100 hp) shows 58 units totaling 1104 hp.

The first place to begin the analysis of any energy system is to determine by direct measurement or indirectly by experience-based estimates the annual energy consumption and annual energy operating cost of the existing system(s). The size of the population of air compressors on Post and the diversity of both unit sizes and end-user patterns of consumption presents quite a challenge at Fort Carson. Once the base case economics are determined, the next step is to estimate what percent of the annual average CA production and electrical operating cost is wasted from 1000s of small to medium leaks. This is best accomplished by a walk-thru survey that samples representative areas of the CA consumers. Mr. Moskowitz's estimate appears quite plausible at approximately 30 percent of Post-wide production with some very low use areas having much higher percent leak rates.

The vast majority (1242 units, 95 percent) are small (<<5 hp, avg. ~2 hp) and located through out the Post, many dedicated to Motor Pools. The average "duty cycle" on the small, ~2 hp units is probably only ~33 percent because a third of the units are never used (emergency backup only), and the two thirds that are active, on average, only 50 percent loaded. Also, these units only operate an av-

erage of 2200 hrs/yr. "Duty cycle" is defined as the average operating load as a percent of the unit name plate at full load.

Descriptive Scope

Implement a CA leak reduction program, initially done by an outside contractor who specializes in identifying, quantifying, and repairing CA leaks. Once the CA leak reduction program approach and methods are "installed" and shown to be successful, the program could be continued with on-Post contractor personnel.

Data and Assumptions Used for Economics

1. 1300 air compressors between 1 and 100 hp post-wide
2. Two distinct size populations exist. Larger compressors totaling 58 units and 1104 hp, range from 5 to 100 hp, averaging 19 hp. Smaller compressors totaling 1242 units range from 1 to 3 hp, avg. 2 hp for a total of 2484 hp.
3. The 1242 small compressors average 2 hp and 67% are actually operated at 50% load for an average operating load of 0.67 hp each. They operate 2200 hrs/yr.
4. The 58 small compressors average 19 hp and 67% are actually operated at 50% load for an operating load of 832 hp. They operate 2200 hrs/yr.
5. An effective CA leak reduction program can reduce the current leak rate from an annual average of 30% to an annual avg. of 5%, saving 25%.
6. The annual ongoing average expense (labor plus materials) for implementing the leak repair program is estimated at $6,500 per year. Initially the program could cost up to $10,000 for the first year through an outside specialist. However, the average cost for the following years through an inside contractor should be approximately $6,500/yr.

Savings Calculation

The first exercise is to calculate the total annual cost to make CA.

The typical, small avg. 2 hp name plate unit has an avg. annual load of 2 hp X 67% operate X 50% loaded = 0.67 hp. The annual energy consumption and cost for all the small units are 1242 units X 0.67 hp/unit X 0.746 hp/kW X 2200 hr/yr = 1,363,500 kWh/yr costing $59,600/yr at 0.0437/kWh.

The same calculation for the 58 larger units (5 to 100 hp, totaling 1104 hp or avg. 19 hp/unit) is 58 units X 19 avg. hp/unit X 0.746 kW/hp X 67% operate X 50% loaded X 2200 hr/yr = 60,800 kWh/yr costing $26,500/yr.

The total electrical operating cost for the 1300 units is estimated to be $59,600 + $26,500 = $86,100/yr.

The gross savings, before the annual ongoing leak reduction maintenance expenses of $6,500/yr, are 25% of $86,100/yr or $21,500/yr. The net annual savings are $21,500 - $6,500 = $15,000/yr.

Cost Estimate Calculations

There is no capital cost for this EOM. Table 57 summarizes the benefits of implementing ECM PW-05.

Table 57. ECM PW-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$15.0K
Capital Cost ($)	0
Simple Payback (years)	Immediate
Comments	Lay up

Status/Recommendations for Further Work

Request proposals for the initial outsourcing of the CA leak reduction program.

ECM PW-06

Facility: Fort Carson
Area: Post wide air compressors
Description: Lower the pressure set point on most of the post-wide air compressors to satisfy end user requirements at lower operating cost.

Background

The typical air compressor operates at its maximum design output pressure, typically 120 psig, even though most end-user requirements are 100 psig or less. It costs more to produce a scfm of 120 psig CA than a scfm of 100 psig CA. The rule of thumb for CA operating costs is that the electric load is 1 percent lower for each 2 psig lower operating pressure. The Fort Carson CA system consists of a very large number of relatively small, individual, de-centralized units located in most of the Post's 40+ buildings. A very recent compressed air study by FEMP, estimated that Fort Carson has approximately 1300 air compressors ranging from 1 to 100 hp, Post-wide. A list of the largest units (5 to 100 hp) shows 58 units totaling 1104 hp.

The first place to begin the analysis of any energy system is to determine by direct measurement or indirectly by experience-based estimates the annual energy consumption and annual energy operating cost of the existing system (s). The size of the population of air compressors on Post and the diversity of both unit sizes and end-user patterns of consumption presents quite a challenge at Fort Carson.

The vast majority (1242 units, 95 percent) are small (<<5 hp, avg. ~2 hp) and located through out the Post, many dedicated to Motor Pools. The average "duty cycle" on the small, ~2 hp units is probably only ~33 percent because a third of the units are never used (emergency backup only), and the two thirds that are active only average 50 percent loaded. Also, these units only operate an average of 2200 hrs/yr. "Duty cycle" is defined as the average operating load as a percent of the unit name plate at full load.

Descriptive Scope

Lower the pressure set point on approximately 80 percent of the Post-wide air compressors to satisfy end user requirements at lower operating cost.

Data and Assumptions Used for Economics

1. 1300 air compressors between 1 and 100 hp post-wide.
2. Two distinct size populations exist. Larger compressors totaling 58 units and 1104 hp, range from 5 to 100 hp, averaging 19 hp. Smaller compressors totaling 1242 units range from 1 to 3 hp, avg. 2 hp for a total of 2484 hp.
3. The 1242 small compressors average 2 hp and 67% are actually operated at 50% load for an average operating load of 0.67 hp each. They operate 2200 hrs/yr.
4. The 58 small compressors average 19 hp and 67% are actually operated at 50% load for an operating load of 832 hp. They operate 2200 hrs/yr.
5. The total annual electric operating cost for the two groups of air compressors was calculated in the previous EOM (PW-04) to be $59,600/yr for <3 hp plus $26,500/yr for 3 to 100 hp. Total CA operating costs are $86,100/yr.
6. It is estimated that 80+% of these compressors can be successfully operated at 100 psig rather than 120 psig.

Savings Calculation

Savings = $86,100/yr x 80% x (120 psig-100 psig) x 1% / 2 psig = $6,900/yr

Cost Estimate Calculations

There is no expense or capital cost for this EOM (Table 54). All that needs to be done is to set the output pressure set point from 120 to 100 psig.

Table 58 summarizes the benefits of implementing ECM PW-06.

Table 58. ECM PW-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$6.9K
Capital Cost ($)	0
Simple Payback (years)	Immediate
Comments	Slam Dunk

Status/Recommendations for Further Work

Request that all parties that operate individual air compressors adjust the output set point pressure from 120 psig to 100 psig or, as low as is acceptable to get the job done.

ECM PW-07

Facility: Fort Carson
Area: Post-wide V-belt driven equipment
Description: Replace standard V-belts with the high efficiency COG V-belts.

Background

A small portion of the Post's electrical load is motor driven ventilation fans, air compressors, etc., that use V-belts in use are standard (lowest 1st cost) V belts. An improved V-belt design is called COG belts which reduce belt transmission losses by 50 percent (from 3 to 1.5 percent) and last twice as long (2 years as opposed to 1 year) as the standard belt. The COG V-belt uses the same sheaves as the standard V-belts.

Descriptive Scope

Replace all standard V-belts with COG type V-belts on motor fan drives, air compressors, etc. to reduce energy consumption, maintenance, and overall initial purchase cost.

Data Used for Economics

- Average Post Electrical load is 14,980 kW costing $5,730K year.
- V-belt driven equipment is 5% of the load and 90% of these are standard V-belts.
- The duty cycle for this equipment is 50% of the year.
- The net energy savings are 3.0% losses for standard belts minus 1.5% for COG V-belt = 1.5%.
- 50% lower maintenance costs at $30/hr for the average belt.
- Total V-belts in use is 300 and maintenance labor per belt change is $30/belt = $9,000/yr.

Savings Calculation

Energy Savings =

$5,730K/yr Post-Wide electric x 5% V-belts x 90% standard belts x 50% duty cycle x 1.5% savings = $1,930/yr.

Maintenance Savings =

50% fewer belt changes on 900 hp of belt x 1 belt/3 hp = 150 changes/yr. 150 changes/yr x $30 /belt = $4,500/yr.

Cost Estimate Calculations

No capital costs and, even though the COG V-belt costs 20 percent more than the standard V-belt, the cost is 40 percent less because it lasts twice as long (2 vs. 1 year).

Table 59 summarizes the benefits of implementing ECM PW-07.

Table 59. ECM PW-07 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$6.4K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay up

Status/Recommendations for Further Work

Return all standard V-belts in stock to supplier and insist or refund and replace all stock equipment with the equivalent COG V-belt.

ECM PW-08

Facility: Fort Carson

Area: Post-wide (excluding Building 8000 – ECMHP-08)

Description: Insulate all bare, aboveground steam and hot water valve bodies and fittings with soft cover, snap-on/off insulation, especially in the mechanical (equipment) rooms.

Background

It is common that, while steam and HW pipes are generally insulated, a number of steam and hot water valve bodies, flanges, and fittings are left uninsulated with temperature range of 160 °F (HW) to 355 °F (HW).

Descriptive Scope

Install soft cover, snap-on insulation covers on all bare valve bodies and associate fittings that are greater or equal to 160 °F.

Data Used for Economics: (excludes HP1860)

- It is estimated that there are approximately 400 uninsulated hot valves, bodies and fittings with an average temperature of >250 °F.
- The total HW and steam cost (excluding Building No. 8000) is $4,640K/yr
- The cost per valve cover (1.5- to 3.0-in. globe valve) is $100 each.
- Un-insulated 2-in. valve at 250 °F loses 3000 Btu/hr.
- The covers reduce 70% of the heat loss.
- Fuel is $5.03/MMBtu (average for all heating plants)
- Average boiler efficiency is 75%.
- Heat loss is over 8700 hrs /yr.
- 70% of heat loss is eliminated with covers.
- Valve covers are $100 each.

Savings Calculation

Method No. 1

Annual $ savings =

800 valve bodies (or other snap-on covers) x 3000 Btu/hr x 70% reduction x 8700 hrs /yr x $5.03/MMBtu/75% efficiency (HW generation) = $79,000/yr

Method No. 2

Annual $ savings =

$4,814,850 (total fuel -excluding B8000) x 15% (heat loss for central HW systems like Fort Carson's) x 10% (total amount of heat loss associated with valve bodies and fittings) = $72,200 (very close to method No. 1 result of $79,000/yr)

Cost Estimate Calculations

Total Cost =

800 valve covers at $100/cover = $80,000

Table 60 summarizes the benefits of implementing ECM PW-08.

Table 60. ECM PW-08 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$79.0K
Capital Cost ($)	$80.0K
Simple Payback (years)	1.0
Comments	Capital project

ECM PW-09

Facility: Fort Carson
Area: Post-wide
Description: Develop long term metering plan.

Background

Energy sub metering is a very valuable tool for improving the management of energy and improving efficiency.

Descriptive Scope

There are seven basic reasons to sub-meter energy:

1. Verify accuracy of utility bills.
2. Allocate energy costs to specific departments, shops or processes.
3. Assign personal accountability for energy uses.
4. Determine equipment efficiency.
5. Audit "before-and-after" energy usage for projects intended to improve efficiency.
6. Identifies performance problems in processes and equipment.

7. Discover opportunities for potential energy efficiency improvements (useful for planning future projects).

Data Used for Economics

- The 2M rule states "If you can't measure it, you can't manage it." By themselves, meters do not save money. They only cost money to purchase and install. Thus, the key to maximize energy savings is to combine the meters with accurate record keeping and then act on the logged energy consumption
- Experience has shown that a well engineered and thought out metering system will result in annual savings of 2% to 5% of the energy cost when the appropriate action is taken based on the logged energy consumption.
- Actual quantity and specific location of electrical to be determined by the Fort Carson PET, with the assistance of outside engineering resources as appropriate.
- Electrical meters @ $2,000 each installed (SQD, Power Logic Units).

Savings Calculation

Annual $ savings =

$5,730,000 x 2% savings from sub-metering = $114,600 saved/yr in electricity

Cost Estimate Calculations

Total Cost =

60 meters x $2,000/electric meter = $120,000 cost

Table 61 summarizes the benefits of implementing ECM PW-09.

Table 61. ECM PW-09 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$114.6K
Capital Cost ($)	$120.0K
Simple Payback (years)	1.0
Comments	Capital Project

Status/Recommendations for Further Work

Evaluate specific locations to sub-meter electricity.

ECM PW-10

Facility: Fort Carson

Area: Post-wide

Description: Promote old fashioned "energy conservation" as an important individual responsibility for all personnel, Post-wide.

Background

The immense size of Fort Carson with a monthly population throughout the year ranging from 12,000 to 18,000 soldiers, family contractors, and administrative personnel present an opportunity, be it ever so challenging, to call on all personnel to make a serious effort to conserve energy at all times, everywhere on Post. The intent behind this ECM is to emphasis the annual financial potential from addressing energy conservation Post-wide and to recognize the fact that the efficient and rational use of energy is not really a technical issue, but rather a people issue.

There are many creative and enticing concepts in which to organize and structure an Energy Conservative Program (ECP). As an example, one successful concept is titled "Gains Sharing" in which a portion of the first year's savings is returned to the individual, group or equally to all personnel from an ECM that has verified savings. The PET should determine what will work best for Fort Carson.

Descriptive Scope

Promote, through the PET, old-fashioned "Energy Conservation" as an important individual responsibility for all personnel, Installation-wide.

Data Used for Economics

- The OLB for Fort Carson fuel for FY02 shows a total of 956,299 MM Btu of fuel was consumed at an annual average unit cost of $5.04/MM Btu for $4,815,000 for the year.
- The OLB for Fort Carson electricity for FY02 shows a total of 131,162,000 kWh of electricity was consumed at an annual average unit cost of $0.0437/kWh for $5,730,000 for the year.
- An effective energy conservation program that broadly involves all personnel has been shown to reduce consumption by 5 to 10%. Conservatively, this study will use 5%.
- Annual expenses for program administration is typically 1% of the annual purchased energy bill.

Savings Calculation

Annual savings potential =

($ 4,815,000 fuel + $ 5,730,000 electricity) x 5% = $ 527,000 /yr

This is the Gross Annual Savings

Cost Estimate Calculations

There is no capital cost to implement the Energy Conservation Program. However, there will be ongoing annual expenses of associated with administration and other operating costs. These costs must be deducted from the Gross Savings to determine the Net annual savings:

Annual expenses = ($ 4,815,000 fuel + 4 5,730,000 electricity) x 1% = $ 105,000 /yr

Net annual savings = $ 527,000 - $ 105,000 = $ 422,000/yr

Table 62 summarizes the benefits of implementing ECM PW-10.

Table 62. ECM PW-10 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$422.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay up

Status/Recommendations for Further Work

Assign the PET the responsibility of establishing and managing the proposed Energy Conservation Program (ECP).

10 Fort Carson Heating Plant Results

This Chapter shows results from ECMs identified in heat plants No. 1860.

Object Statement: Identify ECM solutions that will optimize energy cost (higher efficiency and/or lower consumption) at equal or better output, quality of life, safety, or morale (Table 63).

Table 63. Heating system ECMs summary.

ECM	Energy Conservation Measure Descriptive scope: what, where, why	Type of measure	Net Annual Savings ($k/yr)	Installed Capital Cost ($k)	Simple Payback (yrs)
HP-01	Optimize HW loop temperature at lower levels to meet seasonal and troop occupancy requirements. Control off of HW return rather than holding HW supply constant at 355°F	SD	$15.1	$0.0	Immed.
HP-02	Provide additional steam capability for mess halls and with small direct-fired on demand temperature boost to allow lower HW temperature.	CP	$15.1	$24.0K	1.6
HP-03	Shut off HW generator between 10 p.m. and 4 a.m. during warm months and lower HW recirculation loop flow with VDF yet maintain system pressure.	CP	$19.4	$2.0	0.1
HP-04	Replace old 75 hp DC motor on recirculation pump with an AC motor and add VFD	CP	$11.7	$22.5	1.9
HP-05	Add VFD to 75 hp AC motor on one of the three recirculation pumps	CP	$10.4	$15.0	1.5
HP-06	Install a VFD on the combustion air fan motor and control off of existing continuous O_2 to maximize efficiency over the wide swings in HW demand	CP	$26.3	$17.5	0.7
HP-07	Install "drop-in" economizer in HW generator stack and transfer recovered heat to existing air pre-heater that currently uses steam.	CP	$40.0	$80.0	2.0
HP-08	Insulate all aboveground bare HW and steam piping for Bldg. 1860 Heating Plant distribution system and end users.	CP	$9.9	$8.0	0.8
HP-09	Install capability to isolate selected areas of the HW distribution system to allow maintenance without shutting entire system down.	CP	$874.0	$400.0	0.5
	Total		$1,021.9	$569.0	0.6

Abbreviations: ECM area and categories:
PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost);
LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical;
PET = follow up by the PET

Critical Cost Issues – Heating Plant

Process No. 1: Heating Plant and Fueled-Fired Systems

Task: Identify CCIs for heating plants, fuel and air-conditioning systems that if solved will save $$ and improve the end user operations; CCIs = problems or opportunities that waste a significant amount of $$.

Building 1860 Heating Plant & HW Systems

1. HWG (2@ 40 MMBtu/hr) are too large for summer time loads.
2. Hot water supply temperature is not optimized for the outside ambient temperature and period during the day (typically too hot).
3. Recirculation pumps and combustion fans waste energy because they have inefficient (or no) load following capacity.
4. Must shut down HW to all areas on all HW loops to fix a simple problem on the system. Can not isolate a section of the HW system.
5. Approximately 2% of the HW consuming systems require the other 98% to operate with high distribution losses.
6. No Economizer. Existing combustion air pre-heater does nothing for efficiency.
7. Some good insulation and leak repair opportunities in equipment (REC) rooms.
8. Too many windows are left too wide open for too many hours per day – barracks.

ECM HP-01

Facility

Background

The current practice of controlling system loop temperature at a constant set point of 355 °F throughout the year results in unnecessarily high system losses. A fundamental concept in the optimization of energy systems is to deliver energy (hot water in this case) to the legitimate process end users (building heat, showers, etc.) on an "as needed basis." For the Post's central HW heating plants this would call for controlling the HW system off of return temperature (not supply temperature) to always make sure the last user of the loop is provided high enough HW temperature. Additionally, the HW return temperature set point does not necessarily have to be held constant, but rather can be adjusted seasonally at somewhat lower temperature levels to satisfy the lower system loads during the warm weather months of spring, summer, and fall. Evaluation of this concept might best start at a very conservative HW return temperature set point

of 245 °F, after which the results could be judged. Please note the tables below show the lowest annual historical return temperature during the winter at peak HW loop load to be 230 °F (discussions with Bob Reeves at 7 a.m. on 19 May 2003).

An additional step in driving down the average loop temperature is presented in ECM HP-02. This is based on a first-principle rule of this approach: "Challenge the legitimacy of the existing system loads." In this case, the only HW end-users that require high temperature HW are the Mess Halls, which use HW to make low pressure steam. To fully take advantage of this control strategy allowing the production of lower temperature HW, it is recommended to install four small direct-fired HW heater units to boost the HW to produce flash steam and operate on demand as needed.

Descriptive Scope

Optimize HW temperature at significantly lower levels and control off of HW return temperature instead of HW supply temperature. This control concept will allow the HW supply temperature to float from 355 °F during the winter, high load period, to a low of 295 °F during the summer.

The result is lower annual average HW loop temperature with corresponding system heat losses yet a control concept that continuously provides variable HW supply-side temperature to always satisfy the actual demand on an "as needed basis."

Data Used for Economics

- The fixed system losses through thousands of yards of underground piping with insulation losses are estimated to be 5MM Btu/hr.
- The HW supply temperature is controlled at a constant 355 °F and outside pipe temp is 60 °F.
- The HW return temperature should be adjusted to lower levels based on daily and seasonal heating requirements and Post occupancy levels. The recommended changes from the past practice of allowing constant HW supply temp (355 °F) all year long to allowing the HW supply to "float" based on a conservative, HW return temp (230 °F) is best illustrated in Tables 64 to 65.

Table 64. Existing control based on constant supply temperature of 355 °F.

Season	HW Supply*	HW Return	Delta T	Avg. HW loop temp
Summer	355	290	65	322
Fall	355	260	95	307
Winter	355	239	125	292

Season	HW Supply*	HW Return	Delta T	Avg. HW loop temp
Spring	355	260	95	307
Annual Avg.	355	260	95	307
*profile per Bob Reeves.				

Table 65. Proposed control based on constant return and floating supply temperature.

Season	HW Supply	HW Return	Delta T	Avg. HW loop temp
Summer	230	295	65	262
Fall	230	325	95	277
Winter	230	355	125	292
Spring	230	325	95	277
Annual Avg.	230	325	95	277
Note the annual average loop temp. falls from 307 °F to 277 °F or is 30 °F lower.				

The pressure due to the lower temperature setting will be reduced by approximately 40 psi, from 280 psig (295 psia) to 240 psig (255 psia) for proportionally lower leak rates.

The system leak rate (make up) is assumed to be 5,000 gpd. The leak rate has been as high as 15,000 gpd in the past.

Fuel cost for the 1860 HP in 2002 was $1,200K/yr at an average cost of $5.03/MMBtu.

Savings Calculation

1. Reduced insulation losses =

   5MMBtu/hr x (307-60) - (277-60)/(307-60) or 12.1%savings at 277 °F x 50% for using only half the 30 °F 8700 hr/yr x $5.03/MM Btu/MM Btu = $13.2 k/yr

2. Reduced fuel cost from heat in HW leaks =

   (1-255/295) or 13.5% x 50% for no cost step 1 (15 °F delta T) x 5,000 gpd x 8.33 lb/gal x 365 d/yr x 330 °F x 1Btu/lb °F x $5.03/1,000,000Btu = $1.7K/yr

3. Reduced water cost from leaks =

   (1-255/295) or 13.5% x 50% step1 x 5 kgal/day x 365 days/yr x $1.70/kgal = $200/yr

Total savings =

1 + 2 + 3 = $13.2K + $1.7K + $0.2K = $15.1K/yr

Cost Estimate Calculations

No expense or capital cost. Table 66 summarizes the benefits of implementing ECM HP-01.

Table 66. ECM HP-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$15.1K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Slam Dunk

Status/Recommendations for Further Work

Evaluate the concept by analyzing system performance at different return temperatures at measured loads with existing meters under known conditions of ambient temperature and hourly troop load activity (showers, mess halls, etc.).

ECM HP-02

Facility: Fort Carson

Area: Heating Plant Building No. 1860

Description: Install small HW booster heaters for Mess Hall steam production to further optimization of the HW loop temperature (ref. ECM HP-01) at even lower return temperature further reducing system losses.

Background

Additional optimization of the HW loop temperature (ref. ECM HP-01) is possible at even lower loop temperature and system losses. The only HW end-users that require high temperature HW are the Mess Halls, which use HW to make low pressure steam. To fully take advantage of the control strategy (ref. ECM HP–01, p 38) that will allow the production of even lower temperature HW it is recommended to install four small direct-fired HW heater units to boost the HW to produce flash steam and operate on demand as needed.

Descriptive Scope

Install small HW booster heaters for Mess Hall steam production to further optimization of the HW loop temperature (ref. ECM HP-01) at even lower return temperature further reducing system losses.

Data Used for Economics

- The fixed system losses through thousands of yards of underground piping with insulation losses are estimated to be 5MM Btu/hr.

- The HW supply temperature is controlled at a constant 355 °F and outside pipe temp is 60 °F.
- The HW return temperature should be adjusted to lower levels based on daily and seasonal heating requirements and Post occupancy levels. The recommended changes from the past practice of constant HW supply temp (355 °F) all year long to allowing the HW supply to "float" based on a conservative, HW return temp (230 °F) is best illustrated in Tables 67 and 68.

Table 67. Existing control based on constant supply temperature of 355 °F.

Season	HW Supply*	HW Return	Delta T	Avg. HW loop temp
Summer	355	290	65	322
Fall	355	260	95	307
Winter	355	239	125	292
Spring	355	260	95	307
Annual Avg.	355	260	95	307
*profile per Bob Reeves.				

Table 68. Proposed control based on constant return and floating supply temp.

Season	HW Supply	HW Return	Delta T	Avg. HW loop temp
Summer	230	295	65	262
Fall	230	325	95	277
Winter	230	355	125	292
Spring	230	325	95	277
Annual Avg.	230	325	95	277
Note the annual average loop temp. falls from 307 °F to 277 °F or is 30 °F lower.				

1. The pressure due to the lower temperature setting will be reduced by approximately 40 psi, from 280 psig (295 psia) to 240 psig (255 psia) for proportionally lower leak rates.
2. The system leak rate (make up) is assumed to be 5,000 gpd. The leak rate has been as high as 15,000 gpd in the past.
3. Fuel cost for the 1860 HP in 2002 was $1,200K/yr at an average cost of $5.03/MMBtu.
4. Total cost -- the installed cost for four small direct-fired HW heater units (NG or LP) to boost the HW to produce flash steam is $6,000 per unit.

Savings Calculation

1. Annual $ savings = $ Reduced insulation losses = 5 MMBtu/hr x (307-60) - (277-60)/(307-60) or 12.1%savings at 277 °F x 50% for using only half the 30 °F 8700 hr/yr x $5.03/MM Btu/MM Btu = $13.2 k/yr
2. Reduced fuel cost from heat in HW leaks = (1-255/295) or 13.5% x 50% for no cost step 1 (15 °F delta T) x 5,000 gpd x 8.33 lb/gal x 365 d/yr x 330 °F x 1Btu/lb °F x $5.03/1,000,000Btu = $1.7K/yr

3. Reduced water cost from leaks = (1-255/295) or 13.5% x 50% step1 x 5 kgal/day x 365 days/yr x $1.70/kgal = $200/yr

Total savings = 1 + 2 + 3 = $13.2K + $1.7K + $0.2K = $15.1K/yr

Cost Estimate Calculations:

Total Installed Cost =

4 small, direct-fired booster heaters x $6,000 each = $24.0K

Table 69 summarizes the benefits of implementing ECM HP-02.

Table 69. ECM HP-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$15.1K
Capital Cost ($)	$24.0K
Simple Payback (years)	1.6
Comments	Capital Project

Status/Recommendations for Further Work

Evaluate the concept by analyzing system performance at different return temperatures at measured loads with existing meters under known conditions of ambient temperature and hourly troop load activity (showers, mess halls, etc.).

ECM HP-03

Facility: Fort Carson

Area: Bldg No. 1860 Heating Plant (HP)

Description: Shut off HW generator between 10 p.m. and 4 a.m. during warm months and lower HW recirculation loop flow yet maintain system pressure.

Background

Heating Plant 1860 has extremely low loads from 10 p.m. to 4 a.m. during the warm weather months from May through September. Several years ago, the HW generator was shut off during the night and restarted early morning to save energy. The actual load during these hours is virtually 100 percent steam losses, determined to be 5 MMBtu/hr (see analysis and data in ECMHP-01). The thermal inertia from the miles of large volume underground distribution losses will still provide HW (maybe 230 °F not 355 °F) for the occasional 2 a.m. user that

wants a shower. The system pressure will still be maintained with the VFD recirculation pump but at lower pressure than normal.

Descriptive Scope

Shut off HW generator between 10 p.m. and 4 a.m. during warm months and lower HW recirculation loop flow yet maintain system pressure.

Data Used for Economics

- The fixed system losses through thousands of yards of underground piping with insulation losses are estimated to be 5MM Btu/hr.
- The energy to recover current system supply temperature of 355 °F is estimated to be 30 minutes at 15 MMBtu/hr
- "Warm months" are defined as 15 May to 15 September (4 months)
- Fuel cost is $5.03/MMBtu
- HW boiler efficiency is 70%

Savings Calculation

Annual $ savings =

Existing fuel cost for late night operation = 5 MMBtu/hr x 6 hrs/night x 30 days/month x 4 months/yr x $5.03/MMBtu/70% efficient = $25,900/summer period

Proposed fuel cost for turning system off at night =

$25,900 – recovery cost of 15 MMBtu/hr x 0.5 hr/night x 30 days/month x 4 months/yr x $5.03/MMBtu/70% efficiency = $25,900 - $6,500/summer = $19,400/summer net savings

Cost Estimate Calculations

Total Cost =

The system could be automatically programmed to shut off and restart with an inexpensive timer. Total installed cost is estimated to be $2,000.

Table 70 summarizes the benefits of implementing ECM HP-03.

Table 70. ECM HP-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$19.4K
Capital Cost ($)	$2.0K
Simple Payback (years)	0.1
Comments	Lay up

Status/Recommendations for Further Work

Evaluate the concept by manually testing the system performance and record data on fuel consumption, temperature drop, recovery times, etc.

ECM HP-04

Facility: Fort Carson
Area: Building No. 1860, Heating Plant Complex
Description: Replace old 75 hp DC motor with an AC motor on HW recirculation pump in HP No. 1860 and add a VFD.

Background

One of the existing HW re-circulation pumps has an old, inefficient and unreliable, variable-speed DC motor. The pump is throttled or allowed to by-pass the HW loop at the heating plant to control flow throughout the large daily and seasonal load swings. This wastes a significant amount of electrical pump motor energy.

Descriptive Scope

Install a VFD and a new 75 hp AC motor to replace the DC HWG re-circulation pump to provide the capability of efficiently matching HW flow to the customer's demand on an "as needed" basis.

Data Used for Economics

- Existing HW recirculation pump motor for the HWG is a 75 hp DC motor, 90% loaded and 80% efficient.
- Average annual flow rate load variation is 80%±15%.
- Operating hours are 8700 hrs/yr.
- Electricity cost is $0.0437/kWh, including demand.
- A 75 hp VFD cost $200/hp.
- A 75 hp new motor costs $100/hp.

Savings Calculation

Annual $ savings =

1 x 75 hp x 0.746 kWh/hp x (90% loaded/80% efficient) x 8700 hr/yr x $0.0437/kWh x $(1-.8^3)$ saved

= 548,000 kWh/yr x $0.0437/kWh x 48.8% saved = $11,700 /yr

Cost Estimate Calculations:

Total Cost =

Installed VFD cost = 1 x 75 hp x $200/hp = $15,000

Installed AC motor costs = 1 x 75 x $100/hp = $7,500

Total installed cost = $22,500

Table 71 summarizes the benefits of implementing ECM HP-04.

Table 71. ECM HP-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$11.7K
Capital Cost ($)	$22.5K
Simple Payback (years)	1.9
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

ECM HP-05

Facility: Fort Carson

Area: Building No. 1860, Heating Plant Complex

Description: Install VFD on 75 hp HW recirculation pump in HP No. 1860.

Background

The existing HW recirculation pumps are throttled or allowed to by-pass their loop at the heating plant to control flow throughout the large daily and seasonal load swings. This wastes a significant amount of electrical pump motor energy.

Descriptive Scope

Install a VFD on 75 hp HWG recirculation pump to provide the capability of efficiently matching HW flow to the customer's demand on an "as needed" basis.

Data Used for Economics

- Existing HW recirculation pump for the HWG is 75 hp, 90% loaded and 90% efficient.
- Average annual flow rate load variation is 80%±15%.

- Operating hours are 8700 hrs/yr.
- Electricity cost is $0.0437/kWh, including demand.
- A 75 hp VFD cost $200/hp.

Savings Calculation

Annual $ savings =

1 x 75 hp x 0.746 kWh/hp x (90% loaded/90% efficient) x 8700 hr/yr x $0.0437/kWh x ($1-.8^3$) saved

= 487,000 kWh/yr x $0.0437/kWh x 48.8% saved = $10,400 /yr

Cost Estimate Calculations

Total Cost =

Installed cost = 1 x 75 hp x $200/hp = $15,000

Table 72 summarizes the benefits of implementing ECM HP-05.

Table 72. ECM HP-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$10.4K
Capital Cost ($)	$15.0K
Simple Payback (years)	1.5
Comments	Capital project

Status/Recommendations for Further Work

Prepare RFP for vendors/contractors to submit bids.

ECM HP-06

Facility: Fort Carson
Area: Bldg No. 1860 Heating Plant (HP), Building No. 1860
Description: Install VFD on the combustion air fan of one HW generator and connect the existing continuous stack O_2 measurement to automatically trim fuel-to-air ratio at higher efficiencies.

Background

HP provides high temperature HW at 355 °F to approximately 70 motor pools, 100 barracks, four mess halls and many other community and support buildings. There are two HW generators at 40 MM Btu/hr units that consumed $1,200 k/yr

of NG in 2002 (see the OLB for fuel). The thermal load profile during the week and seasons varies widely from 5 to 30+ MM Btu/hr based on the hourly demand for troop showers and mess hall operations, the seasonal level of soldier occupancy on Post and especially building heat based on ambient temperature.

Descriptive Scope

Install a variable frequency drive on the combustion air fan for the HW generator to provide the capability to efficiently follow the wide swing in daily hot water loads. The control of the VFD on this primary, lead unit, by O_2 will significantly reduce fan motor load throughout the wide daily load variations and increase the average boiler efficiency at lower O_2 levels due to the improved response and precision of the VFD.

Data Used for Economics

- HW generator average load is approx. 18.3 MM Btu/hr throughout the year.
- Total fuel consumption was $1,200,000/yr in 2002.
- Typical daily load swings are 18.3 MM Btu/hr ± 10 MM Btu/hr.
- The existing 30 hp combustion air fans are controlled by inlet dampers with average motor loads of 80%.
- The typical annual excess O_2 in the flue gas at the widely varying loads are 5.5 ± 2 percent with corresponding boiler combustion efficiencies of 75 ± 5 percent.
- The more responsive VFD fan speed control should reduce excess O_2 to 3.5 ± 2 percent to improve boiler efficiency by 1.5% from 75.0% to 76.5%.

Savings Calculation

Annual $ savings =

VFD motor load savings = 30 hp x (80% loaded/88% effic.) x 0.746 kW/hp x 8,000 hr/yr x $0.0437/kWh x ($1-0.7^3$) = $4,700/yr

O_2 with auto trim efficiency savings = $1,200K/yr x (+1.5% efficiency/75%) x 90% run time = $22,600/yr

Total savings = $4,700/yr (electrical savings) + $21,600/yr (fuel) = $26,300/yr

Cost Estimate Calculations

Total Cost =

1. 30 hp x $250/hp = $7,500
2. Upgrade the excess O_2 in-stack sensor with controller to trim air by VFD = $10,000 installed

Total installed cost = 1 + 2 = $7,500 + $10,000 = $17,500 installed

Table 73 summarizes the benefits of implementing ECM HP-06.

Table 73. ECM HP-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$26.3K
Capital Cost ($)	$17.5K
Simple Payback (years)	0.7
Comments	Capital project

Status/Recommendations for Further Work:

Prepare an RFP for vendor/contractor bids.

ECM HP-07

Facility: Fort Carson

Area: Heating Plant Building No. 1860

Description: Install "in-stack" economizer to heat HW generator combustion air by transferring recovered heat to the existing air pre-heater.

Background

The hot water generators (HWG) in HP No. 1860 do not have an economizer to recover waste heat from the stack to pre-heat the 70 °F combustion air into the unit. The typical hot water generator efficiency can be improved by 4 to 5 percent if an economizer is available to recover heat from the flue gas stack for use in preheating make up water. The HW generators would typically not require make up so the best use of recovered stack heat is to pre-heat combustion. The existing units are doing this with hot water that is generated from the hot water generator and that has no added value to the efficiency of the hot water generator. Use recovered stack heat to the air pre-heater with a small run-around hot water loop between the in-stack economizer and the existing air pre-heater.

Descriptive Scope

Install low budget economizer directly in the existing boiler stack by "suspending" a tube bundle in the reinforced/stabilized stack.

Data Used for Economics

- Annual fuel consumption is $1,200K/yr
- Existing annual average boiler efficiency is 75 ± 5 percent.

- The proposed "low budget economizer" to preheat combustion air typically saves 3 to 5% if fuel costs. This work assumes 4%, even though it is easy to make 15 psi steam from boiler exhaust heat.
- The cost to install a "low budget in-stack economizers" for small (<20,000 lb/hr HW generation) is $2000/million Btu.
- The target boiler is 40 million Btu/hr.

Savings Calculation

Annual $ savings = $1,200K/yr x 4% savings = $40,000/yr

Cost Estimate Calculations

Installed Cost = 40 million Btu/hr x $2,000 installed cost per million Btu/hr = $80,000

Table 74 summarizes the benefits of implementing ECM HP-07.

Table 74. ECM HP-07 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$40.0K
Capital Cost ($)	$80.0K
Simple Payback (years)	2.0
Comments	Capital project

Status/Recommendations for Further Work

Identify approved vendors and contractors for solicitation of requests for proposals.

ECM HP-08

Facility: Fort Carson

Area: Boiler house Building #1860 and end users

Description: Insulate all aboveground bare HW and steam piping; especially in the mechanical (equipment) room.

Background

It is common that, while steam and HW pipes are generally insulated, a number of steam and hot water valve bodies, flanges, and fittings are left uninsulated with temperature range of 160 °F (HW) to 340 °F (Steam).

Descriptive Scope

Install soft cover, snap-on insulation covers on all bare valve bodies and associate fittings that are greater or equal to 160 °F.

Data Used for Economics

- It is estimated that there are approximately 80 uninsulated hot valves bodies and fittings with an average temperature of 250 °F.
- The cost per valve cover (1.5- to 3.0-in. globe valve) is $100 each.
- Un-insulated 2-in. valve at 250 °F loses 3000 Btu/hr.
- The covers reduce 70% of the heat loss.
- Fuel is $5.03/MMBtu (average fir HP No. 2351).
- Average boiler efficiency is 65%.
- Heat loss is over 8700 hrs /yr.
- 70% of heat loss is eliminated with covers.
- Valve covers are $100 each.

Savings Calculation

Annual $ savings =

80 valves x 3000 Btu/hr x 70% reduction x 8700 hrs /yr x
$5.03/MMBtu/75%efficenciy (HW generation) = $9,900/yr

Cost Estimate Calculations

Total Cost = 80 valve covers at $100/cover = $8,000

Table 75 summarizes the benefits of implementing ECM HP-08.

Table 75. ECM HP-08 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$9.9K
Capital Cost ($)	$8.0K
Simple Payback (years)	0.8
Comments	Capital project

ECM HP-09

Facility: Fort Carson

Area: Building No. 1860 Heating Plant

Description: Install capability to isolate selected areas of the HW distribution system to allow maintenance without shutting entire system down.

Background

Currently the HW system must be 100 percent shut down to repair any portion that develops heavy leaks or otherwise fails. This represents serious inconvenience to the thousands of installation personnel in the form of lost time, increased maintenance/repair TAT, and significant cost consequences of not being mission ready. It is estimated that this occurs, on the average, of 4 days per year.

Descriptive Scope

Install sufficient HW valves in selected critical end-user portions of the HW distribution system to provide the capability of isolating approximately 10 subsystems. This would allow 9 sub-systems to operate normally while repairs are done to the problem system.

Data Used for Economics

- Typically the system requires total shutdown two times/yr for 2 days each or 4 days/yr.
- Sub-system isolation eliminates 90% of the end user impact
- 4 days/yr of system downtime is 32 work hrs/yr
- Lost time cost an average of $25/hr
- +10% TAT = $865,000/yr
- The consequential cost of "not" being mission ready is $500K/yr

Avoided Cost Savings Calculation

The 100 percent total system shut down for 4 days/yr vs. 10 percent shut down will inconvenience 90 percent fewer customers. The direct, indirect, and consequential costs of no building heat or hot water for 500 post personnel for 4 days per year are estimated as follows:

1. Lost time = 5000 people x 90% x 32 hrs/yr x $25/hr = $360K/yr
2. Increased TAT (see example for Building 8000 Maintenance Complex) = $865K/yr per 10% TAT x 4 days/250 days/yr or 1.6% = $13.8K
3. Unknown "consequential cost" as a direct consequence of 4 days, not mission ready = $500K/yr

Total avoided cost = 1 + 2 + 3 = $360K/yr +$14K/yr + $500K/yr = $874K/yr

Cost Estimate Calculations

Total Cost =

Assume that system isolation can be accomplished using valves. Install 20 valves and also underground piping at $10,000/valve and 1,000 ft of pipe at $200/ft = $400,000

Table 76 summarizes the benefits of implementing ECM HP-09.

Table 76. ECM HP-09 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$874.0K
Capital Cost ($)	$400.0K
Simple Payback (years)	0.5
Comments	Capital project

Status/Recommendations for Further Work

Private industry would recommend investments to provide system capability that allows for continued operation in the event of sub-system failures. As a direct consequence, it has a negative impact on (1) productivity, (2) TAT, (3) Safety and, (4) mission readiness.

11 Fort Carson Maintenance Complex Results

Object Statement: Identify ECM solutions (Table 77) that will optimize energy cost (higher efficiency and/or lower consumption) at equal or better TAT, maintenance quality, safety, or morale.

Table 77. Maintenance complex ECMs summary.

ECM	Energy Conservation Measure Descriptive scope: what, where, why	Type of measure	Net Annual Savings ($k/yr)	Installed Capital Cost ($k)	Simple Payback (yrs)
MC-01	Determine which boiler has the highest efficiency and operate it for most of the annual hours	SD	$4.2	$0.0	Immed.
MC-02	Survey and fix 30% of 100 steam traps	LU	$10.0	$0.0	Immed.
MC-03	Insulate bare steam valves flanges and fittings	CP	$7.9	$8.0	1.0
MC-04	Add shut off controls to Joy air compressors after compressed air leaks are repaired	CP	$1.2	$0.6	0.5
MC-05	Replace “once thru” CSU cooling water to cool 2 – 75 hp Sullair air compressors with packaged, closed loop system	CP	$11.7	$2.0	0.2
MC-06	Repair seals to windows in the 239 office area	CP	$10.8	$17.5	1.6
MC-07	Install fast open/close doors on high traffic bays	CP	$26.2	$90.0	3.4
MC-08	Install Solar wall on south side of building 8000	CP	$53.8	$190.0	4.4
MC-09	Replace 10 of 12 roof top units	CP	$120.0	$120.0	1.0
MC-10	Extend exhaust stack on Dynos to eliminate fumes entering intake ventilation	CP	$18.5	$3.2	0.2
	Total		$264.3	$431.3	1.6
Abbreviations: ECM area and categories: PW = Post-Wide; HP = Heating Plant; L = Laundry; MC = Maintenance Complex; SD = slam dunk (no cost); LU = layup (small expense/no capital), CP = capital project; NA = not applicable; NE = not economical; PET = follow up by the PET.					

Critical Cost Issues – Maintenance Complex

Task: Identify CCIs for Maintenance Complex that if solved will save $$ and improve the end user operations

CCIs = problems or opportunities that waste a significant amount of $$

Task: Identify CCIs for/in Wheeled Vehicle and Heavy Shop that if solved will save $$ and improve the end user operations

CCIs = problems or opportunities that waste a significant amount of $$

1. SullAir air compressors use "once through" city water for the summer for cooling.
2. Compressor (s) operate at output pressure higher than required for end users.
3. It is unknown which of the two boilers is more efficient for base loading.
4. Ten of the 12 roof top units (RTUs) to heat outside air during winter are 30+ years old, high maintenance (no parts), inefficient and not doing the job.
5. Too much winter air infiltration from slow high bay doors results in high heating costs and very uncomfortable working conditions.
6. Need to provide more space heat on "spot" basis and move 80 °F + warm air from top of high bay to 60 °F floor.
7. Prep area with grind and sand and paint booth both in same area causes dust in paint and fume in Prep.
8. No steam trap maintenance program except to fix "if" trap blow through causes an operation problem.
9. Central vacuum systems (tailpipe suckers) run fully loaded all day long using excessive energy.
10. Dyno exhaust is sometimes pulled back into the building outside air ventilation intakes causing poor IAQ.
11. Old (34+ yrs) inefficient metal frame windows in 239 project area result in very uncomfortable working space in summer and winter.
12. Lights are left on when not needed at nights and weekends from 5 to 15% of the time depending on the area.
13. Engine repair performance on Dyno fails approximately 4% of the time and must be reworked.
14. Some compressed air leaks in 8000 complex.

Budget and Operating Cost Analysis – Maintenance Complex

Purpose: To determine the economic contribution (k$/yr) from incremental process related improvements in the DOL maintenance complex (Table 78).

Table 78. Ten-percent "What If" benefits from potential process optimization initiatives.

No.	Description/Basis	Existing k$/yr	-10% TAT
1.	Operating budget:	$10,408	$1,040
2.	Operating Cost:		
	2a. Labor (20% variable)	$8,100	$162
	2b. Energy/utilities (20% variable) -Electricity $234.0K/yr -Fuel $174.0K/yr -Subtotal $408.0K/yr	$408	$8
	2c. Operating Supplies (95% variable)	$1,000	$95
	2d. G&A and other (0% variable)	$600	$0
	Total Operating Cost	$10,108	$265
3.	Residual Value	$300	$775
Summary for "+10% What If" benefits			**k$/yr**
1. New value from +10% TAT			$775
2. New value from +10% Labor (improved productivity)			$648
3. New value from +10% Materials and supplies			$5
4. New value from +10% Energy			$33

ECM MC-01

Facility: Fort Carson

Area: Building 8000 Maintenance Complex

Description: Determine which boiler has the highest efficiency and operate it for most of the annual hours.

Background

Building 8000 has three small, low pressure (15 psig) boilers (2 @ 3.7 MMBtu/hr, 1 @ 1.3 MMBtu/hr). The current practice is to operate the two 3.7 MMBtu/hr units (approx. 3400 lb/hr or 100 hp) for an equal number of hours each year (i.e., run one at a time for 3 months and then switch to the other for 3 months). Typically, boilers, even with identical specifications will, for a number of reasons, operate at different levels of performance (efficiency, reliability, emissions, etc.). Often the respective boiler efficiencies of two identical units are found to be 1 to 3 percent different. For example, Boiler No. 1 might have an efficiency of 75 percent and Boiler No. 2 might have an efficiency of 77 percent.

Descriptive Scope

This ECM recommends running the most efficient boiler all the time. This requires measuring the efficiency of the two primary boilers and designating the most efficient unit to be the lead unit with the most number of operating hours.

Data Used for Economics

- The boilers operate at an average of 75% efficiency due to their wide variation daily in load. Since they are small, they do not justify the capability of high efficiency load following and all of the "bells and whistles."
- The result is that one unit randomly will degrade in efficiency more than the other. They may be different by 1.5 to 2.5%.
- The total fuel cost to Building 8000 Maintenance Complex is $175,000/yr (see OLB).
- Experience would say that the two boilers could easily be operating at up to 2% average efficiency difference for an average efficiency of 75%. This would mean an average annual fuel consumption difference of 2%/75% or 2.67% and would be so small that it would not justify further investigation.

Savings Calculation

Annual $ savings =

$175,000/yr x 90% time possible x 2.67% = $4,200/yr

Cost Estimate Calculations

Total Cost = No capital cost.

Table 79 summarizes the benefits of implementing ECM MC-01.

Table 79. ECM MC-01 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$4.2K
Capital Cost ($)	$0.0
Simple Payback (years)	Immediate
Comments	Slam Dunk

Status/Recommendations for Further Work

For this ECM simply establish a policy to know the efficiency difference between the boilers and run the most efficient unit at all times possible. Boiler and efficiency measurement vendors would be more than pleased to test the unit at no charge. Assign possible individuals to make this happen.

ECM MC-02

Facility: Fort Carson
Area: Building 8000 Maintenance Complex
Description: Repair failed steam traps.

Background

The steam trap maintenance responsibility has apparently been neglected for many years. The result is many of the steam traps have failed partially open, allowing "live" steam to enter the condensate return system and be vented (wasted). The traps have apparently never been properly surveyed and are only fixed after wasting steam for many months.

Descriptive Scope

Formally initiate a steam trap maintenance program and repair/replace failed traps. There are approximately 100 steam traps in building 8000. It is estimated that approximately 15 percent need to be repaired and 15 percent need to be replaced. Initially, (year No. 1) this is best done by an outside steam trap "specialist," not necessarily a steam trap vendor.

Data Used for Economics

Data on existing system

- Approximately 100 steam traps throughout the 8000 maintenance complex.
- The trap losses are estimated to average 1,000 lb/hr for 24 hrs /day, 6 days/wk, 26 wks/yr.
- Fuel for steam $60K/yr and trap losses
- 15% of the 100 traps are estimated to be partially failed and will cost $100 each to repair
- 15% of the 100 traps are recommended for replacement at $300 each

Savings Calculation

Annual $ savings =

Gross savings = $60K/yr fuel for steam x 20% trap losses = $12K/yr
Annual expense (see item 4 below) = $2.0K/yr

Net annual savings = Gross – Annual expense = $12.0K - $2.0K = $10.0K/yr

Cost Estimate Calculations

Total Cost =

Repair cost = 15% x 100 traps x $100/trap (repair) = $1,500

Replacement cost = 15% x 100 traps x $300/trap (replace) = $4,500

Total expense (every 3 years) = $1,500 + $4,500 = $6,000

Total expense/yr = $6,000 (expense over 3 years)/3 years = $2,000/yr

Table 80 summarizes the benefits of implementing ECM MC-02.

Table 80. ECM MC-02 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$10.0K
Capital Cost ($)	$0.0K
Simple Payback (years)	Immediate
Comments	Lay-up

Status/Recommendations for Further Work

Have reputable steam trap supplier survey and repair/replace all failed traps. Thermodynamic disc or impulse traps and orifice type traps are not as efficient as thermostatic designs.

ECM MC-03

Facility: Fort Carson

Area: Building 8000 Maintenance Complex

Description: Insulate all bare, steam and hot water valve bodies, flanges and fittings with soft cover, snap-on/off insulation.

Background

It is common that, while steam and HW pipes are generally insulated, a number of steam and hot water valve bodies, flanges, and fittings are left uninsulated with surface temperatures of 338 °F (100 psig steam). This ECM is only for the 8000MC facility, the rest of the post is covered in ECM PW-07 range of 160 °F (HW) to 355 °F (HW).

Descriptive Scope

Install soft cover, snap-on insulation covers on all bare valve bodies and associate fittings that are greater or equal to 160 °F.

Data Used for Economics (excludes HP1860)

- It is estimated that there are approximately 400 uninsulated hot valves, bodies and fittings with an average temperature of >250 °F.
- The total HW and steam cost (excluding Building No. 8000) is $4,640K/yr.
- The cost per valve cover (1.5- to 3.0-in. globe valve) is $100 each.
- Un-insulated 2-in. valve at 250 °F loses 3000 Btu/hr.
- The covers reduce 70% of the heat loss.
- Fuel is $5.03/MMBtu (average for all heating plants).
- Average boiler efficiency is 75%.
- Heat loss is over 8700 hrs /yr.

Savings Calculation

Method No. 1:

Annual $ savings =

80 valve bodies (or other snap-on covers) x 3000 Btu/hr x 70% reduction x 8700 hrs /yr x $5.03/MMBtu/75%efficenciy (Boiler efficiency) = $7,900/yr

Method No. 2:

Annual $ savings =

$80K/yr (total fuel for B8000) x 15% (heat loss for central HW and steam systems like Fort Carson's) x 10% (total amount of heat loss associated with valve bodies and fittings) = $7,200 (very close to method No. 1 result of $7,900/yr)

Cost Estimate Calculations

Total Cost = 80 valve covers at $100/cover = $8,000

Table 81 summarizes the benefits of implementing ECM MC-03.

Table 81. ECM MC-03 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$7.9K
Capital Cost ($)	$8.0K
Simple Payback (years)	1.0
Comments	Capital project

ECM MC-04

Facility: Fort Carson

Area: Building 8000, Maintenance Complex (MC)

Description: Add shut off controls to Joy air compressors after compressed air leaks are repaired.

Background

The two 75 hp Joy rotary screw air compressors in the maintenance complex are almost always shut off during non-work hours. This is to the credit of the MC staff. It was, however, noticed by Mr. Moskowitz, the FEMP contractor who audited the Post's compressed air systems in May 2003 that the compressor was continuously operating throughout the day, largely for supplying numerous leaks with very little actual activities legitimately consuming air. Measurement of operating compressor showed 231 scfm of compressed air output, 206 scfm of which (89 percent) were determined to be system leaks. Recommendation with supported economics are provided in this report to "Initiate an annual compressed air lead reduction program – including the 8000 maintenance complex (see ECM PW-04)

Also, Mr. Moskowitz noted that the Joy units were not provided with auto start/stop control mode capability. If the leaks were repaired, this secondary control system would have shut the compressor off during such low compressed air usage periods (231 scfm output minus 206 scfm leaks = 25 scfm actual usage)

Descriptive Scope

Fix compressed air leaks and then add an auto start/stop control mode to cycle the compressor on/off based on pressure rather than continuously throttling the inlet flow.

Data Used for Economics

- The compressor would use the auto stop/start (off/on) control mode for 30% of the time during an 8 hour/day, 5 day/wk period, saving 70% of the motor load.
- 75 hp unit.
- 90% motor efficiency.
- Electricity cost $0.0437/kWh.
- Five-day work week.

Savings Calculation

Annual $ savings =

75 hp x 0.746KW/hp x (70% loaded/90% efficient) x 8 hr/day x 30% off x 5 day/wk x 52 week/yr x $0.0437/kWh = $1,200/yr

Cost Estimate Calculations

Total Cost =

The cost of the auto start/stop control addition is $400 per Joy compressor plus $250 installation or $600 total

Table 82 summarizes the benefits of implementing ECM MC-04.

Table 82. ECM MC-04 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$1.2K
Capital Cost ($)	$0.6K
Simple Payback (years)	0.5
Comments	Capital project

Status/Recommendations for Further Work

- Fix leaks
- Add on/off control

ECM MC-05

Facility: Fort Carson

Area: Building 8000, Maintenance Complex (Joy air compressors)

Description: Replace “once thru” CSU cooling water to cool 2–75 hp Sullair air compressors with packaged, closed loop system, air cooled system.

Background

The Joy air compressors use CSU water for cooling which is dumped directly into the sewer. This is a waste of expensive water during times in which drought is causing water shortages. This unfortunate situation was brought to the PEO Team’s attention by Paul Parker, ITT Maintenance, who has made a special effort to remedy the problem. The situation probably exists because no cooling tower water was available nearby.

Descriptive Scope

Option A

Install a packaged air-cooled, closed loop cooling system to eliminate the wasteful situation of "once through" cooling.

Option B

Install a solenoid actuated valve on "once-through" cooling flow and interlock with air compressor starter

Data Used for Economics

- Paul measured the flow rate and found it to be 7 gpm.
- The cost of CSU city water is $1.46/kgal and the sewer charge is $2.84/kgal.
- The flow of city water is continuous all year, although the air compressor is only operated 8 hrs /day, 5.5 days/wk and 52 wks/yr = 2,300 hrs /yr or 26% of the time.
- An alternative is to install a solenoid operated valve on the city water that is activated by the air compressor starter to eliminate 74% of the once-through water consumption.
- Installed cost of the solenoid valve solution is $1500.
- The installed cost of packaged closed loop cooler is $25,000.

Savings Calculation

Option A

Gross $ Savings = 7 gpm x 60 min/hr x 8760 hr/yr/1000 gal x ($1.46/kgal (water) + $2.46/kgal (sewer)) = $15,800/yr

Operating expense for closed loop system = (1 hp pump + 2 hp fan) x 0.746 kW/hp x 80% loaded/80% efficient x 2300 hr/yr x $0.0437/kWh = $300/yr

Net savings = $15,800 - $300 = $15,500/yr

Option B

$15,800/yr x (2300 hrs/yr/8760 hrs/yr or 74%) = $11,700

Cost Estimate Calculations:

Total Cost =

Option A = Closed loop system = $25,000

Option B = Solenoid valve to save water = $2,000

Table 83 summarizes the benefits of implementing ECM MC-05.

Table 83. ECM MC-05 economic and benefit summary.

Net Savings, Cost and Payback	Economics Option A	Economics Option B
Net Operating and Energy Savings ($/yr)	$15.5K	$11.7K
Capital Cost ($)	$25.0K	$2.0K
Simple Payback (years)	1.7	0.2
Comments	Saves 100% water	Saves 74% water

Status/Recommendations for Further Work

PET selects an option and expedite project.

Updated Information (as of 11 July 2003)

The PET has developed an alternative solution for a closed loop system that can be designed and assembled internally at Fort Carson and will cost approximately $3,000 for time and materials.

ECM MC-06

Facility: Fort Carson
Area: Building 8000 Maintenance Complex–Office Area No. 239
Description: Upgrade or replace long window wall in the 239 office area to reduce heat loss and air infiltration.

Background

The 239 office area has 100 ft of windows x 6 ft high that are old, metal frame windows that do not close tightly. The result is excessive heating augmented by many small electric heaters. Summertime conditions are also poor due to solar gain and the recent loss of the awning that was very old and weathered.

Descriptive Scope

Upgrade long window by the following combined projects.

Option A

- Install thin foam rubber gaskets on windows to eliminate air infiltration.
- Insulate metal window frame with foam rubber to reduce conduction.
- Replace awning.

Option B

Completely replace the 100 ft section of windows (approximately 25 windows)

Data Used for Economics

- 8000 Maintenance Complex steam and HW cost $80/yr (see OLB), 20% for No. 239 area.
- Twenty electric heaters at 1500 watts each operate for 3,000 hrs per year.
- Windows are 25 units, 6 ft high, 4 ft wide, 100 lin. ft, 20 ft of gasket per window.
- Electricity cost $0.0437/kWh.
- New windows cost $700 each installed.

Savings Calculation

Option A =

Annual $ savings =

$80,000/yr (steam and HW) x 20% for area No. 239 x 50% losses due to window heat loss/gain and air infiltration x 60% reduction with changes = $4,800/yr

20 electric heaters x (1,500 watts/1,000 watts/kW) x 3000 hrs /yr x $0.0437/kWh x 75% eliminated = $3,000

Total savings = [$5,600 (heating loss eliminated) + $3,000/yr (electric heater usage eliminated)] = $7,800/yr

Option B =

Annual $ savings =

$80,000/yr (steam and HW) x 20% for area No. 239 x 50% losses due to window heat loss/gain and air infiltration x 90% reduction with changes = $7,200/yr

20 electric heaters x (1500 watts/1000 watts/kW) x 3000 hrs /yr x $0.0437/kWh x 90% eliminated = $3,600

Total savings = [$5,600 (heating loss eliminated) + $3,000/yr (electric heater usage eliminated)] = $10,800/yr

Cost Estimate Calculations

Total Cost =

Option A = $1,500 (foam rubber gaskets) + $2,000 (Foam rubber insulation on metal frames) + $4,000 (new awning) = $7,500

Option B = 25 windows x $700 = $17,500

Table 84 summarizes the benefits of implementing ECM MC-06.

Table 84. ECM MC-06 economic and benefit summary.

Net Savings, Cost and Payback	Economics Option A	Economics Option B
Net Operating and Energy Savings ($/yr)	$7.8K	$10.8K
Capital Cost ($)	$7.5K	$17.5K
Simple Payback (years)	1.0	1.6
Comments	Capital project	Capital project

Status/Recommendations for Further Work

The best long term solution is Option B.

ECM MC-07

Facility: Fort Carson

Area: Building 8000 Vehicle Maintenance Complex

Description: Replace high traffic overhead doors and seals with energy efficient models to greatly reduce building heating loads.

Background

The overhead doors open and close too slowly and let cold air into high traffic areas. Also, seals are poorly designed and fail on high traffic doors within a few months resulting in continuous winter air infiltration.

Descriptive Scope

Replace five doors in Vehicle Maintenance Shop with new, fast action, low infiltration doors to significantly reduce infiltration, lowering annual heating costs

Data Used for Economics

- There are dozens of overhead doors throughout the complex.
- There are five doors in the Vehicle Maintenance Shop that are very high traffic volume.
- High air infiltration increases building heat load by 25%.
- The shop has a heating cost of $175,000/yr.
- Replacing five doors in the Vehicle Maintenance Shop will decrease the heating requirement by 25%.
- Each new door will cost $18,000.

Savings Calculation

Annual $ savings =

$175,000/yr (heating cost in building 8000 x 50% for vehicle maintenance shop) x 60% (due to air infiltration) x 50% (reduction from new doors) = $26,200/yr

Cost Estimate Calculations:

Total Cost =

5 new doors x $18,000/door = $90,000 installed

Table 85 summarizes the benefits of implementing ECM MC-07.

Table 85. ECM MC-07 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$26.2K
Capital Cost ($)	$90.0K
Simple Payback (years)	3.4
Comments	Capital project

ECM MC-08

Facility: Fort Carson

Area: Building 8000

Description: Install solar wall on south side of Building 8000.

Background

Building 8000 contains a high-bay vehicle maintenance facility and office space. Heating is provided to the building with 12 roof mounted unit heaters for the high-bay area and a steam heat system for the office space. Each roof top unit (RTU) has a gas burner rated at 1,000,000 Btu/h and at 15,000 cfm fan. In the high bay are there is one thermostat controlling the temperature in the zone served by the RTU. The fans typically are operated continuously to provide fresh air to the vehicle maintenance area with roof top exhaust fans to remove vehicle fumes not captured by the vehicle exhaust capture system. Temperature control is sometimes difficult and more fresh air is required at times to maintain comfortable and healthy conditions for the maintenance staff. The building is rectangular in configuration with the long axis being East/West providing a large Southern exposure.

Descriptive Scope

The proposed ECM is to install a specific solar collector system called "SOLARWALL" on the south-facing wall of Building 8000 to provide supplemental heat and ventilation to Building 8000. "SOLARWALL" uses a transpired collector technology where a dark, perforated metal wall is installed on the south-facing side of a building, creating approximately a 6-in. (15-cm) gap between it and the building's structural wall. The dark-colored wall acts as a large solar collector that converts solar radiation to heat. Fans mounted at the top of the wall pull outside air through the transpired collector's perforations, and the thermal energy collected by the wall is transferred to the air passing through the holes. The fans then distribute the heated air into the building through ducts mounted near the ceiling. By preheating ventilation air with solar energy, the technology removes a substantial load from a building's conventional heating system, saving energy and money. Fort Carson currently has a SOLARWALL installation on a helicopter hanger. The staff at Fort Carson reports that the solar system functions well.

Data Used for Economics

- Sales representatives for SOLARWALL have been contacted by the Fort Carson staff regarding installation of the SOLARWALL product for Building 8000.
- The preliminary estimate provided by the company "Energy Inc." has reviewed and the benefits provided by the installation appear to be reasonable and beneficial to Fort Carson.
- Additional cost and benefit detail is required from the supplier.

Savings Calculation

"Energy Inc" estimates that a 10,200 square ft that will save $53,808 annually. Additional detail is required from "Energy Inc." on benefit and cost estimates.

Cost Estimate Calculations

Cost estimates for the installation are $190,000 for the 10,200 sq ft wall.

Table 86 summarizes the benefits of implementing ECM MC-08.

Table 86. ECM MC-08 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$53.8K
Capital Cost ($)	$190.0K
Simple Payback (years)	3.5
Comments	Capital project

ECM MC-09

Facility: Fort Carson

Area: Building 8000 Maintenance Complex

Description: Replace 10 of 12 roof top units.

Background

The existing 10 direct-fired roof top units (RTUs) have the following issues:

1. They are more than 30 years old
2. They are not efficient
3. They do not keep the high bay area warm
4. They consume approximately 1 man-year of maintenance labor
5. They require replacement parts that do not always exist
6. They require replacement parts that, when available, can be very expensive.

The impact on TAT is significant. Typically, 2 or 3 of the units are out of commission at all times. Two much larger units were replaced last year for approximately $35,000.

Descriptive Scope

Replace all ten units with new high efficient models that save energy, maintenance, improve morale, and decrease TAT.

Data Used for Economics

- Existing RTUs consume $95K/yr of NG at $5.03/MMBtu.
- New units would be 15% more thermally efficient and 10% higher electric efficiency.
- Each RTU has a 30 hp fan (15,000 cfm) and are approximately 5000,000Btu/hr.
- A 10% decrease in TAT saves the maintenance complex $775,000/yr (see TAT analysis).

- Maintenance cost on the existing units are $35K/yr for labor and $35K/yr for spare parts = $70K/yr.
- Maintenance on new units is 20% of existing units.
- New units can be installed for $12,000 each.

Savings Calculation

Annual $ savings =

1. Natural gas savings = $95K/yr x 15% = $14,250
2. Electric savings = 30 hp x 0.746 kW/hp x 10% = $3,000
3. Maintenance savings = $70K/yr x 20% = $14,000
4. TAT savings = $775K/yr per 10% improvement x 1% (0.1% overall improvement) = $7,750
5. Morale/productivity = $8,100K/yr total labor cost x 1% improvement in productivity = $81,000

Total savings = 1+2 +3+4+ 5 = $120,000

Cost Estimate Calculations

Total Cost =

10 units x $12,000 each = $120,000 installed

Table 87 summarizes the benefits of implementing ECM MC-09.

Table 87. ECM MC-09 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$120,000
Capital Cost ($)	$120,000
Simple Payback (years)	1.0
Comments	Capital project

Status/Recommendations for Further Work

ECM MC-10

Facility: Fort Carson
Area: Building 8000, Maintenance Complex – outside wall at Dynos
Description: Extend exhaust stack on Dynos to eliminate fumes entering intake ventilation.

Background

The Dynometers "Dynos" measure engine horsepower at different engine RPM for testing engine performance before and after overhauls. The exhaust from the engines during operations is piped up an outside wall through four, 8-in. diameter stacks with the top of the stacks level with the roof. Unfortunately, the exhaust fumes drift across the roof and are pulled back into the building through "fresh" supply air. The result is that people inside smell the fumes and complain of headaches and nausea.

Descriptive Scope

Extend the exhaust stack 16 ft higher with 4-in. diameter sections of pipe. The 50 percent smaller diameter will increase the exhaust gas velocity by a factor of four pushing the exhaust plume 30+ ft higher than the top of the stack extension such that the fumes are not drawn back into the building intake.

Data Used for Economics

The installed cost of four sections of 16-ft long, 4-in. diameter pipe is $50/ft.

Savings Calculation

Annual $ savings =

1. Better IAQ improves morale and productivity = $7,750
2. Basic safety and health (no lost time) = $3,000
3. Shorter TAT (decrease of 0.1%) = $7,750

Total = 1 + 2 + 3 = $18,500

Cost Estimate Calculations

Total Cost =

4 pipe extensions x 16 ft/extension x $50/ft = $3,200

Table 88 summarizes the benefits of implementing ECM MC-10.

Table 88. ECM MC-10 economic and benefit summary.

Net Savings, Cost and Payback	Economics
Net Operating and Energy Savings ($/yr)	$18,500
Capital Cost ($)	$3,200
Simple Payback (years)	0.2
Comments	Capital project

12 Conclusions and Recommendations

Conclusions

Fort Leonard Wood

This study has identified dozens of potential ECMs at Fort Leonard Wood for the following plant utility systems:

- Post-wide (PW)
- Heating Plant (HP)
- Laundry (L)
- Maintenance Complex (MC).

A total of 26 of the ECMs were economically quantified, and when implemented, will reduce the post's annual energy and operating costs by approximately $1,963,275. The capital investment required to accomplish these savings is approximately $1,929,300 and results in an average simple payback of 1 year.

Fort Carson

This study has identified dozens of potential ECMs at Fort Carson for the following plant utility systems:

- Post-wide (PW)
- Heating Plant (HP)
- Maintenance Complex (MC).

A total of 29 of the ECMs were economically quantified, and when implemented, will reduce the post's annual energy and operating costs by approximately $2,117,250. The capital investment required to accomplish these savings is approximately $1,250,300 and results in an average simple payback of 0.6 years.

Since the scope of this project was limited to a few areas of the installation, there are many additional opportunities for energy savings. The primary areas that are worthy of more analysis include family housing, the barracks complex, and the hospital.

Recommendations

This study recommends a continuation of Process Optimization for more building/process areas. The purpose of the Level I Process Optimization Assessment is to determine the economic "potential" for significant cost reduction from process changes. This is accomplished in a Level I analysis by identifying solutions to critical cost issues and estimating the economics for the top ideas. The 1-week analysis of multiple complex processes is not intended to be (nor should it be) precise. The quantity and quality of the process improvements identified in the Level I audit suggests that significant potential exists. Both Fort Leonard Wood and Fort Carson can accomplish these potential cost savings and growth in capabilities by pursuing an aggressive program of Process Optimization.

Low-cost/no-risk ("slam dunk") process improvement ideas from this Level I analysis are typically implemented quickly. However, the greatest profit opportunities need to be developed further by a Level II effort. This effort most often requires a combination of in-house and outside support. Based on the success of the Level I process/profit audit, a Level II effort is recommended. A Level II analysis "guesses at nothing – measures everything," quantifying both the Level I and new Level II ideas. The results are a set of demonstrated process improvements based on hard numbers. A specific Level II scope and approach as to how to use on-site and off-site resources are best jointly developed by review and discussion of results documented in this Level I report. CERL and expert consultants can provide both installations guidance and further assistance in identifying a specific Level II scope of work, respective roles, and the most expeditious path forward. This begins with a formal review of this report, combined with a planning session to organize the Level II program.

Appendix A: "Rules of Thumb" for Utility System ECOs

Rules of Thumb for Energy Conservation Opportunities (ECOs) are intended to provide energy professionals and part time practitioners with guidelines for identifying and evaluating ECOs. The Rules of Thumb are shortcut methods, factors, typical percentage results, and formulas to calculate ECO performance and to estimate economics of savings and installed cost.

Energy Management and Program Economic Guidelines

Plant Energy Audits

Initiate formal plant energy audits by trained audit teams that identify ECOs that can reduce the facility's Purchased Energy Cost (PEC) by 15 to 25 percent over a 1 to 3-year period with typical paybacks under 2 years.

Unit Energy Costs

Develop incremental unit energy costs as a Cost Basis of Savings (CBOS) to calculate ECOs savings on a variable cost basis.

One Line Balance (OLBs)

Develop One-Line Balances for steam, electricity, compressed air, etc. with accuracy of ± 20 percent. OLBs are used to identify opportunities in their respective utility system and to assist in providing a basis for cost savings.

Strategic Energy Plan

Implement a formal Strategic Energy Plan (SEP) that typically results in annual savings of 2 to 3 percent of the annual purchased energy cost (PEC).

Energy Performance Index (EPI)

Develop and track an overall Energy Performance Index (Btu/unit product) as a linear regression model to monitor program performance. The EPI generally saves up to 0.5 percent of the PEC.

Plant Utility Indices

Establish and track plant utility indices as efficiency guidelines to save up to 1 percent of the annual PEC.

Sub-Metering

Install sub-metering saving 2 percent of the PEC by providing accountability, accounting, troubleshooting, project verification, and overall feedback on the financial contribution from the EM Program.

Optimize Water Treatment

Optimize water treatment performance to save two to five times the annual cost of water treatment.

Shut it Off

Shut off energy to facility systems when not needed. This typically saves more than 1 percent of the annual PEC.

Steam Systems

Boiler Efficiency

Optimize flue gas conditions to reduce percent 0_2, flue gas temperature (°F) and CO concentration. Incremental changes in flue gas conditions improve a nominal 150 PSI boiler efficiency (Table A1).

Table A1. Improvement in nominal 150 psi boiler efficiency resulting from changes in flue gas conditions.

Flue Gas	Efficiency	
Condition	**Change**	**Change**
Excess 0_2 (%)	-1.0%	+0.66%
Temp (°F)	-10°F	+0.25%
CO (ppm)	-100 ppm	+0.10%

Maximize Use of Highest Efficiency Boiler

Maximize the operating hours and loading of the highest efficiency boilers to typically reduce fuel consumption by 1 to 2 percent at zero cost.

Run Minimum Safe Number of Boilers

Operate minimum number of required boilers to safely and reliably meet the facility's steam needs resulting in typical savings of 1 percent of the annual fuel expense at no cost.

Reduce Boiler Steam Pressure

A 10 psig reduction in boiler pressure set point will reduce boiler fuel as shown (case where no steam turbines are used):

- 150-200 psig saves 0.2%
- 100-149 psig saves 0.4%
- 50-99 psig saves 0.6%

Heat Loss versus Insulation Thickness

One inch of insulation reduces bare pipe heat loss by approximately 70 percent. Two inches reduces the remaining 30 percent loss by 70 or 21 percent for 91 percent total. Three inches reduces the last 9 percent by 70 percent or approximately 6 percent for a total of 97.3 percent. Two inches is the "economic" thickness for 80 percent of all applications. Well-insulated distribution systems for a fifty million BTUs/hr. steam system will typically have 2 to 4 percent heat loss. Losses for this system with average insulation performance will lose 5 to 8 percent while poorly insulated systems can lose 10 to 15 percent or more. The insulation losses from the steam distribution system are fixed losses independent of steam flow rate.

Pipe Insulation

Insulate steam systems when pipe surface temperatures are >160 °F in cold climates or >190 °F in warm climates. Fuel costs, ambient temperatures, insulation costs and safety issues must also be considered. Similarly, paybacks usually occur in 18 to 48 months.

Removable, Soft Insulation

Installation of soft-cover, blanket insulation on uninsulated steam valve bodies, flanges and fittings will typically result in a 6-month payback for $3.00/mm Btu boiler fuel.

Steam Trap Losses

A typical steam trap loses 1 to 2 lb/hr of live steam during normal operation. A failed trap can lose 10 to 100 pounds per hour of live steam. Trap replacement can have a payback of 1 year while trap repair can result in a payback of only a few months.

Steam Leaks

Establish a leak identification and repair program. Leaks for a well-maintained plant are <1 percent, typical plants 2 to 4 percent, and poorly maintained plants can be 10 percent or more (Table A2).

Table A2. Steam leak rules of thumb.

Type	Flow Rate (lb/hr)	Blow Length (in.)	$/yr @5.00/klb
Wisp	2	41	90
Small	10	12	450
Medium	30	36	1350
Large	170	72	7500

Sizing Condensate Lines

Condensate return piping should typically be 50 percent of the diameter of the steam pipe it serves.

HVAC and Refrigeration System ECO Rules of Thumb

HVAC&R Unit Costs

The incremental cost for plant steam is typically $5.00/klb, basis: $3.00/mm Btu fuel, 80 percent boiler efficiency, 50 percent condensate return and BFW treatment. The incremental cost for chilled water is $50/k ton-hour. Basis: 5 ¢/kWh @ 0.90 kW/ton, including cost for CT fans, pumps and chilled water pumping.

Chiller Efficiencies

The typical, 15-year-old existing industrial centrifugal chiller operates at an approximate COP of 5.0 and 0.80 kW/ton (0.90 kW/ton with CHW and CT energy). A new, high efficiency, chiller can operate at 0.55 kW/ton (0.65 kW/ton with CHW and CT energy).

HVAC & R Formulas

The following formulas are useful in calculating industrial and commercial heating, air-conditioning, and refrigeration loads:

1. Sensible Heat, Btu/hr. = 108 x CFM x Delta T (°F)
2. Total Cooling, Btu/hr = 4.5 x CFM x Delta H (Btu/lb dry air)
3. Water Side, Btu/hr = 500 x GPM x Delta T (°F)
4. Latent Load, Btu/hr = 0.67 x CFM x Delta Grains
5. Fan Load, HP = CFM x Delta P (in. wc)/4000
6. Duct Pressure Drop (in. wc) Delta P/100 ft = 0.15 in. wc
7. Fan Laws: CFM, SP, HP
8. CFM2/CFM1 = RPM2/RPM1
9. SP2/SP1 = $(RPM2/RPM1)^2$
10. HP2/HP1 = $(RPM2/RPM1)^3$

Increase CHW Temp

For each 1 °F increase in CHW supply set point the chiller compressor motor load will decrease by 1.5 percent. This is a zero cost ECO.

Decrease CTW Condenser Temp

For each 1 °F decrease in CTW to the chiller's condenser, the chiller compressor load will decrease by 1 percent.

CTW to Centrifugal Chiller

Centrifugal refrigeration machines use 3 GPM of condenser CTW per ton for a 10 °F Delta T.

CTW to Single Stage Absorber

Single stage absorption refrigeration machines use 4.5 GPM of CTW per ton with an 18 °F Delta T. This is more than twice the cooling load of a centrifugal unit.

Steam to Single Stage Absorber

A single stage absorption chiller consumes 17 lb/hr of 15 psig steam per ton CHW produced.

Steam to Two Stage Absorber

Two stage absorption chillers consume 10 lb/hr of 125 psig steam per ton CHW produced.

Cooling Tower Efficiency

An efficient cooling tower (CT) will achieve a 7 °F approach to the design wet bulb temperature. Typically, a CT only achieves 9 to 12 °F approaches to wet bulb resulting in a 2 to 5 percent increase in chiller compressor load. CTW unit cost 8¢/Kgal. @ 5¢/kWh.

Compressed Air Systems

Organize for Success

Form a small, part-time Compressed Air Team (CAT) responsible for implementing CA ECOs.

CA Audit

Initiate a formal audit of CA generation, distribution, and process end-users.

Unit cost of CA

Incremental, electricity only, unit cost of CA is 18¢/kcf at 5.0¢/kWh based on 24 BHP/100 scfm plus 20 percent for auxiliaries.

Total Unit Cost of CA

Total (variable and fixed) unit cost of CA is 33¢/kcf. This includes 18¢/kWh electricity, 3.8¢/kcf debt service, 2.5¢/kcf operating and maintenance labor, 2.5¢/kcf for materials and supplies and 1.2¢/kcf for taxes, insurance, miscellaneous. The variable Cost Basis of Savings (CBoS) for CA is 18¢/kWh, other costs are considered essentially fixed.

Critical Cost Issue List

Identify major critical cost issues (problems or opportunities) in the CA systems or operations that represent higher than normal annual costs.

Total Economic Impact of CA

Develop the total annual cost of CA on the facilities bottom-line. This includes all direct costs (typically variable), indirect costs (typically fixed) and all consequential cost of CA such as reliability, product quality, environmental, etc. that are a direct consequence from a CA problem. Rule of Thumb CA No. 4.4 illustrates variable and fixed costs only of 18 and 15¢/kWh. Consequential cost might add another 3 to 7¢/kcf.

One Line Balance

Develop estimates the CA flow (kcfm) and cash flow (k$/yr.) that "accounts" for all kcfm generation, distribution (by PSI level) and consumption of all major end-users. This is done by the CA Team estimating average generation and consumption.

Pattern of Use

Estimate a typical 7-day system load profile (maximum, average, minimum), load duration curve, and hours of use of major compressor units as a base case for identifying and quantifying CA ECOs.

Run Minimum Number Machines

Operate the minimum number of machines to reliably, safely, and economically meet facility requirements.

Maximize Use of Efficiency Machines

Maximize the operating hours of use and load of the highest efficiency machines.

Balance Loads

Match (equalize) output of machines of near equal efficiency to eliminate blow off (venting).

Part Load Operation

Optimize part load efficiency by load following with reciprocating or rotary screw units to keep centrifugal machines from venting.

Minimize Blow-off (Venting)

Integrate the control systems of multiple large centrifugal units with special compressor controls to minimize blow-off, trend efficiency, and diagnose mechanical problems.

Minimize Use of Least Reliable Machines

Identify least reliable and/or highest maintenance machines to minimize use and evaluate replacement economics.

Intercooler Temperature

Economically provide optimum low temperature cooling tower water to intercoolers and after coolers. Each 1 °F lower cooling tower water supply temperature reduces the compressor motor load by 0.15 percent. Reduce winter CTW to minimum.

After Cooler Performance

The typical after cooler should remove 70 percent moisture and requires 3 GPM of CTW per 100 SCFM.

Optimize CTW Treatment

Optimize cooling tower water treatment to provide good heat transfer (low scale) and reliability (low corrosion).

Once Through Cooling

Eliminate once-through cooling with city water by installing a cooling tower. Once through city water is $1.00/kgal while CTW is 8¢/kgal.

Lube Oil Cooler

Properly maintain lubricating oil cooler performance for efficiency and reliability. Compressor capacity can be reduced by 10 percent or more if the lube oil cooler is not functioning properly.

Synthetic Lube Oil

Use synthetic oil on reciprocating and screw machines that are low oil consumers. Saves 1 percent compressor motor energy.

Motor Drives

Specify energy efficiency motors to save 2 to 6 percent of motor load with 2-year payback.

Alternate Drives

Evaluate back pressure steam turbine drives (1.0¢/kWh) and/or reciprocating or combustion turbine drives with heat recovery as cogeneration topping cycles.

COG Belt Drive

Replace standard V-belts with high-efficiency COG type V-belts saving 1.5 percent of drive energy for 3-month payback without sheave change.

Air Intake Location

Air intake should be from coolest location, typically outside. A 5 °F temperature difference reduces motor load by 1 percent. Compressor room air is often 10 to 40 °F hotter than outside air depending on whether it is summer or winter.

Inlet FilterDelta P

Maintain inlet filter DP below 6- to 8-in. of wc. The motor load increases 5 percent for each 5 in. of inlet pressure drop.

Inlet Guide Vanes (IGV)

Replace butterfly inlet valve with inlet guide vane (IGV) design to reduce compressor motor load by 2 to 4 percent for a 9 to 18 months payback.

Energy Efficiency Dryers

Specify a high efficiency dryer such as "Heat of Compression" and operate unit properly. "Heatless" dryers are not recommended as they use and dump CA to regenerate desiccant.

Dew Point Control

Optimize dew point by controlling to meet requirements on "as needed" basis rather than using timer controls.

Recover Heat of Compression

The heat of compression is typically rejected to the cooling tower. However, 95 percent of this heat (approximately 230,000 Btu/hr per 100 HP of compressor drive) can be recovered with a plate heat exchanger to preheat boiler makeup water. Air-cooled units can be directly used as building heat during winter and exhausted during summer.

PM Program

Establish a predictive and preventive maintenance program. A complete program typically saves 2 to 3 times its cost.

Reduce Compressor Pressure

Motor load is reduced by 1 percent for each 2 psig reduction in pressure set point at the compressors. Pressure can be adjusted down to a point that is limited by the highest pressure user. This is a no cost ECO.

Point-of-Use Pressure Control

Allow the set point to automatically float based on a control signal from the highest pressure user. This can generally average an additional 2 to 4 psig pressure reduction at the compressor saving 1 to 2 percent.

Lower High Pressure User

Reduce the pressure requirements of the high-pressure users. These could be caused by sticking air cylinders, operating unnecessary CA equipment or wasteful operator practices. An example of a old, high consumption technology is high-pressure paint sprayers versus HVLP units.

Reduce System Pressure Drop

Identify and relieve piping system pressure drop bottlenecks.

Air Traps

Establish a formal trap program. A failed trap that removes condensate can lose 10 to 100 scfm costing $950 to $9500/yr @ 18¢/kcf (approximately $100/cfm-yr).

Fix Leaks

CA leak rates at industrial facilities range from 10 to 40 percent of air production. A facility with 1000 scfm of production at 25 percent leaks loses approximately $24,000/yr. Individual leaks range from small (1 scfm) costing $100/yr, to medium 10 scfm leaks costing $1,000/yr, large 30 scfm costing $3,000/yr. Purchase an ultrasonic leak detector ($1,000–$3,500) to support the program.

ID Peakers

Identify and reduce CA loads that strongly contribute to peak demand. These users actually cost up to twice the average cost per scfm (36 vs. 18¢/kcf).

Optimize Processes to Use Less or Zero CA

Re-engineer CA out of the processes by technology and/or procedural changes. Savings of 15 to 40 percent have been achieved.

Storage Tanks

Install surge/storage tanks at high volume, short period, pulsing users.

PRV for Emergency Conditions

Install a normally closed high to low system Pressure Reducing Valve (PRV) to backup of low-pressure system.

Decommission Idle Distribution Legs and Machines

Install airtight blank flanges to isolate and depressurize idle legs. Valve off idle machines. If leaks account for 25 percent of system capacity, and 20 percent of the systems are idle, then system-wide energy costs will be reduced by 5 percent.

Management and CAT Feedback

Formally provide facility management with the financial contribution of the CA Program on a quarterly basis. Provide plant management, CAT members and end users with economic results on specific projects and overall program accomplishments.

Appendix B: Fort Carson, CO, Collaborative Targeted Assessment

Fort Carson, Colorado

Collaborative Targeted Assessment

(CTA)

May 2003

Funded by:

U.S. DOE Federal Energy Management Program,

Industrial Facilities Initiative,

Under subcontract to Oak Ridge National Laboratory

Frank Moskowitz

4108 East Molly Lane

Cave Creek, AZ 85331

Phone 480 563-0107°

FORT CARSON

Collaborative, targeted, assessment

What is a CTA

Purpose

CTA's are being offered to FEMP's federal industrial customers to assist them in identifying energy efficiency opportunities in motor-driven systems, including pumping, fan, compressed air systems, steam systems, process heating, and other energy consuming processes. The purpose of the walk-through assessment or CTA is to create an awareness of the magnitude and scope of energy efficiency opportunities in the compressed air system. FEMP believes that the CTA is an opportunity for plant people to learn how to apply the tools and techniques in a one on one situation. It is not meant to replace a comprehensive, fully instrumented system audit. Typical on site time is about two days.

Scope of Work

CTA's performed for FEMP are conducted in a manner consistent with the system assessment principles included in DOE's Compressed Air Challenge™ Fundamentals of Compressed Air Systems and Advanced Management of Compressed Air Systems training programs. The auditors are professionals who demonstrate a thorough understanding of these principles and documented experience in applying them in plant assessments. All plant assessments are solutions neutral – promotion of products and services during the plant walkthrough or in the written report is highly inappropriate.

FEMP Support

This CTA was funded under subcontract with Oak Ridge National Laboratory, by the Federal Energy Management Program (FEMP) Industrial Facilities Initiative. For additional information on FEMP's Industrial Facilities Initiative and other FEMP Services please contact Michaela Martin at Oak Ridge National Laboratory at (865) 574-8688, or Alison Thomas DOE Program Leader at (202) 586-2099, or Randy Jones, DOE central regional office at (303) 275-4814.

Assessment Goals

This CTA included an analysis of both the demand side and the supply side of the compressed air system. The assessment at Fort Carson included:

- Identified components of the supply side, including compressors, primary storage, filters, treatment equipment, drains, and system controls.
- Determined major uses of compressed air

- Identified inappropriate uses of compressed air and made recommendations for alternatives
- Identified usage reduction opportunities from leak management
- Identified any air quality problems
- Determined highest point of use pressure requirements and likelihood of whether requirements are valid
- Determined highest volume point of use and ability of existing system to respond
- Determined effectiveness of control strategies in meeting demand and made recommendations for improvement

Measurements during the Assessment

Measurements or a baseline of the compressed air system is required to gain a basic understanding of the dynamics occurring in the plant. A full data logging treatment was beyond the scope of this assessment. Pressure measurements were recorded at critical applications as well as key points on the supply side. Flow measurements were not taken during this assessment. All flow data obtained was interpreted by compressor performance profiles or from manufacturer's specs.

Overview of Fort Carson

Fort Carson, the Mountain Post, is located on the south side of the City of Colorado Springs, Colorado, in El Paso County. The installation stretches south along Interstate 25 into Pueblo and Fremont counties. The cantonment area of Fort Carson is located in the northern part of the installation. Fort Carson houses the 3 Armored Cavalry Regiment (ACR), 3rd Brigade, 4th Infantry Division (ID), 43 ASG, and 10 Special Forces (SF). As a result, the Base has several vehicle maintenance facilities for tanks and other tracked and wheeled vehicles. A complete tank engine depot maintenance and dynamometer testing facility is also located at Fort Carson. The Butts Army Air Field (AAF) is an active runway and hangar facility used primarily by Army rotary-wing aircraft (Figure B1)

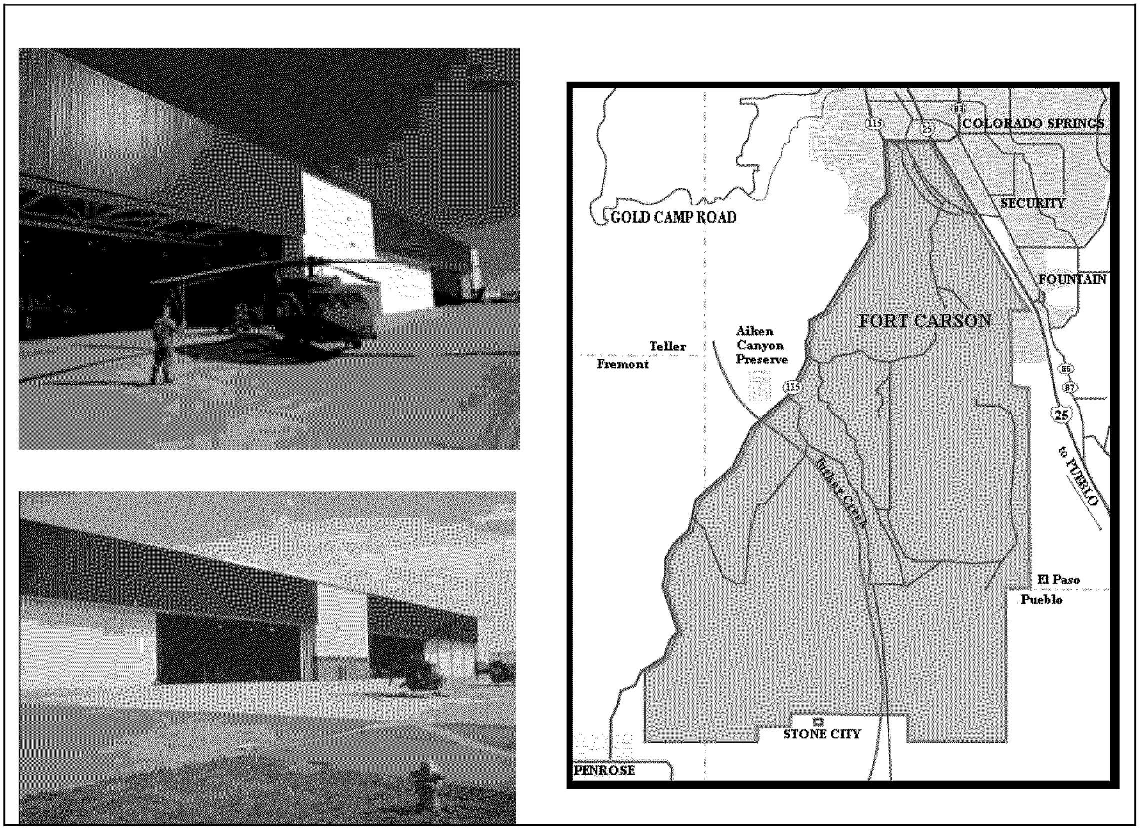


Figure B1. Butts Army Air Field (AAF) runway and hangar facility.

Fort Carson's Air Compressors

Ft. Carson's Air Compressors					
Building Number	Horsepower	RPMs	Brand	Power Requirments	Model#
207	5	1750	Quincy	230/460, 6.6 Amps	325-13
221	7.5	1745	Ingersoll	230/460, 20/4/10.2 amps	64D7
301	7.5	1730	Devil Biss	220/440, 21.0/10.5 Amps	VAS-S102
330	20		Vacudent	230/460, 53.2/26.6 amps	MDC2025RH
501			Sullair		12BS-60H
633	7.5	1740	Quincy		340
634	7.5	1740	Speedair	220/440, 22.6/11.3 Amps	12936E
636	7.5	3500	Speedair	230/460, 18.2/9.1 Amps	5F565
749	7.5	1755	Campbell Havsfield	230/460, 22/11 Amps	
749	7.5	1725	Campbell Havsfield	230/460, 22/11 Amps	
1382	15	1765	Champion	220/440, 40/20 Amps	OEH-36-15
1392	15	1760	Saylor Beall	230/460, 38/19.5 Amps	PL-451512
1682	15	1740	Dayton		2N987A
1692	15	1760	Dayton	220/440	2N987D
1864	15	1760	Baldor	230/460	
1864	7.5	1760	Lincoln	230/460	
1982	15	1760	Baldor	230/460	M2513T
2082	15	1760	Baldor	230/460	M2513T
2426	5	1740	Baldor		
2427	30	3470	Sullair		
2427	30	3470	Lincoln		
2492	15	1735	Lincoln	220/440	
2692	15	1760	Baldor	230/460	M2513T
2792	15	1760	Baldor	230/460	M2513T
2992	15	1760	Baldor	230/460	M2513T
3092	15	1760	General Electric	230/460	
3192	20	1750	Wagner	230/460	
3292	20	1750	Wagner	230/460	
3857	5	1740	Speedair	230/460	
3887	5	1735	Pacer	200	
3897	7.5	1745	Lincoln	230/460	
3900	7.5	1725	Baldor	230/460	
7426	15	1760	Baldor	230/460	
7440	15	1760	Baldor	230/460	
8000	75	1775	Sullair	230/460, 192/96 Amps	16-75HH
8000	75	1775	Sullair	230/460, 192/96 Amps	16-75HH
8004	100		Ingersoll	230/460, 140/70 Amps	SSR-EP100
8030	25	1750	Worthington	230/460, 64/32 Amps	
8030	20		Worthington		15 BN-12
8030	15		Worthington	230/460, 38/19 Amps	15EN12
8030	25	1750	Lincoln	230/460	
8030	25	1750	Lincoln	230/460	
8030	25	1750	Lincoln	230/460	
8100	20	1760	Baldor	230/460	
8142	5	1420	Lincoln	208	
8142	40	1775	Sullair	230/460	
8152	20	1750	Magnete	230/460	
8200	7.5	1725	Champion	230/460, 22/11 Amps	HR7D-25
8300	10	1725		230/460, 28/14 Amps	MSV-40808602
8300	10	1725		230/460, 28/14 Amps	MSV-40808601
9072	15	1760	Baldor	230/460	
9604	5	1725	Lincoln	208	
9604	15	1760	Lincoln	230/460	
9604	15	3495	U.S. Motor		
9620	10	1700	Baldor	230/460	
9628	15	1755	Lincoln	230/460	
9633	40		Sullair		
9550	7.5	1725	Baldor	230/460	

Annual Electricity Costs

The following calculations were used to determine electrical costs

(bhp) x (0.746) x (hours) x (cost)

Motor efficiency

Where:

bhp = typical break horsepower at load
hours = annual hours of operation (use 8760)
Motor efficiency = will use 0.9

- Electrical Rates from customer info: weighted average = $0.05
- Compressors run 365 days per year but at various duty cycles
- Assume 24/7 run time for following calculations

Equipment status during logging May 12th and 13th

Total compressor horsepower of 1,105

$/kWh = 0.05

Hours = 8760 (24 hours a day, 365 days per year operation equals 8760 hours)

Motor efficiency = 90%

(1105 x 0.746 (8760 hrs) (0.05)) ÷ 0.90 = $ 401,172.00 / yr

With typical 50% duty cycle the energy costs = $ 200,000/yr

With over 1,300 air compressors and over 40 separate buildings, the control of the individual compressors is determined by each buildings requirements. For the most part all the reciprocating compressors (horsepower range from 5-20) operate on a pressure switch utilizing a start/stop method of control. This allows them to shut down when the pressure in the distribution piping has been satisfied. There are however eight rotary screw air compressors which range from 30 horsepower to 100 horsepower. These larger compressors utilize a suction throttle type inlet control and do not have any means of shutting down automatically because that particular option was never installed on the compressors. In addition to not being able to shut down, compressors with this type of inlet control are not very energy efficient. When this type of compressor is outputting minimal flow, they will still consuming nearly 85% of their full load power. During the data collection on 12-13 May, the rotary compressors were not even required to do minimal or no demand, yet they were all running. Leaks were allowing them to stay on. The next page shows a chart of the compressors and the energy they can consume while they run with out supporting any production.

Unnecessary Energy Expense

Building Number	Compressor Type and Horsepower	Usage	Energy wasted for a 4,500 hour year
2427 Auto Craft	Two 30 HP Sullair Rotary Screws	One compressor running and one standby	Running compressor has no auto stop feature. Runs all day regardless of requirements. $ 5,000 annually wasted
8000 ITT Maintenance	Two 75 HP Sullair Rotary Screws	One compressor running and one standby	Running compressor has no auto stop feature. Runs all day regardless of requirements. $ 12,000 annually wasted
8142	One 40 HP Sullair Rotary Screw	One compressor running	Running compressor has no auto stop feature. Runs all day regardless of requirements. $ 6,000 annually wasted
9633	One 40 HP Sullair Rotary Screw	One compressor running	Running compressor has no auto stop feature. Runs all day regardless of requirements. $ 6,000 annually wasted
All buildings	All compressors	Compressors running to feed leaks	All buildings had leaks. Given the $200,000 (4,000,000 kWh/yr) annual energy bill for compressed air I estimate the total leakage rate at 30%. This would equate to $ 60,000 per year (1,200,000 kWh/yr)

Fort Carson is using $ 200,000 annually to supply compressed air to the entire facility based on a 50% duty cycle, of which:

- $ 29,000 is wasted annually on compressors which are lacking controls to shut them down
- $ 60,000 is wasted annually on compressed air leaks throughout the entire facility

Based on the information provided and what was observed on May 12th and 13th, Fort Carson is currently spending about $ 200,000 or 4,000,000 kWh per year on electrical energy for the compressed air system. This value is based on a number of assumptions that need to be confirmed and corrected after the acquisition of hard facts. The first is the load profile of production. Data was only collected for a period of 24 hours. There are over 1300 air compressors throughout the entire Fort. Some run and some do not. Some are shut off when not needed and some are left on 24/7. Therefore the dollar amounts may not represent the true "one year or 8760 hours as indicated. The second assumption is the cost of energy. The $0.05 figure does not take into account the additional charges for maintenance and water usage where required.

The Estimate of Energy Costs used $0.05/kWh. As better information becomes available the Estimate can easily be corrected. Each building has its own unique requirements for compressed air. For example: building 8000 has two 75 hp wa-

ter cooled rotary screw compressors with no dryer. Only one is required but has no ability to shut down due to lack of controls. The cost per cfm in this building would be approximately $80/cfm/yr. The year is based on a 4500 hour time period. A hose reel leaking at 15 scfm would cost (15 x $80) = $ 1,200 per year. On one site visit, numerous leaks were noted Building 8030 (GI Motor Pool) has six tank mounted reciprocating compressors with rated horsepower ranges from 15 to 25. Each compressor is set up for start/stop operation using a pressure switch. Only leaks could waste energy in this building.

General Observations

The compressed air systems at Fort Carson supply each building individually with the proper quality and pressure as required for the specific process. Smaller reciprocating type compressors are used for the controls on HVAC equipment. This air required filtration and moisture removal using a compressed air refrigerated dryer. Larger reciprocating compressors up to 25 horsepower are used for motor pool and equipment repair. The quality of air and pressure for this application would be different. Some buildings utilized dryers to dry the air to remove moisture and some buildings that had chilled water available, used the compressors after-cooler to reduce temperature and remove the moisture. No one complained of moisture in the compressed air lines being a problem. I did notice however the compressors were all operating between 120-130 psig. Most air tool requirements are around 90 psig. Lowered pressure by 20 psig in any building would result in 10% energy savings.

All maintenance on the compressed air systems throughout Fort Carson is performed by LB&B Associates, Inc. From my observations of the compressors, all basic maintenance such as filters, lubricants, filter elements, belts, etc. are changed on a regular basis. Compressor rooms were all in excellent cleanliness and layout. Lubricant levels on all rotary screw compressors were right on the mark and temperatures were all within acceptable range. Normal building maintenance visits occur every 90 days unless a request is made to perform a repair if needed. This quarterly maintenance is very typical in the compressed air industry and from my observations is working very well at Fort Carson.

Compressed air leaks were prevalent in most buildings I visited. This is very typical in all buildings utilizing threaded and coupled pipe for the distribution system. The only fix here is to alert the personnel in each building about the cost of a compressed air leak. At Fort Carson the average leak costs $ 80 per cfm per year, which could get expensive. Repair procedures are shown on page 10.

Plant Issues

Some other concerns, which are addressed in this report, are:

- Pressure requirements at the point of use (high pressure not valid)
- Small percentage of end use driving pressure higher for rest of facility.
- Excessive leaks
- Automation for compressors not utilized

The Anatomy of a Compressed Air System

To help define all of the opportunities for enhancing compressed air system energy efficiency and quality improvements, let's categorize the three basic areas of a compressed air system: supply, transmission, and demand.

Supply

Supply can be summed up as the compressor room. It's where the air is compressed, treated and sent out into the system. Since demand drives the system, supply must be reactive and fill the required needs. To effectively manage energy reduction efforts within this phase requires replacing the consumed supply using a minimum amount of energy. At this point, the proper quality must be created.

Transmission

Transmission is the method of getting air to the point-of-use, which includes the pipe, hose, fittings, valves and dedicated storage. The goal of the piping system is to get the compressed air to the point-of-use in a timely manner, while maintaining the proper quality, which includes pressure and quantity. To save energy in the transmission stage, focus needs to be directed toward minimizing the pressure drop in the system.

Demand

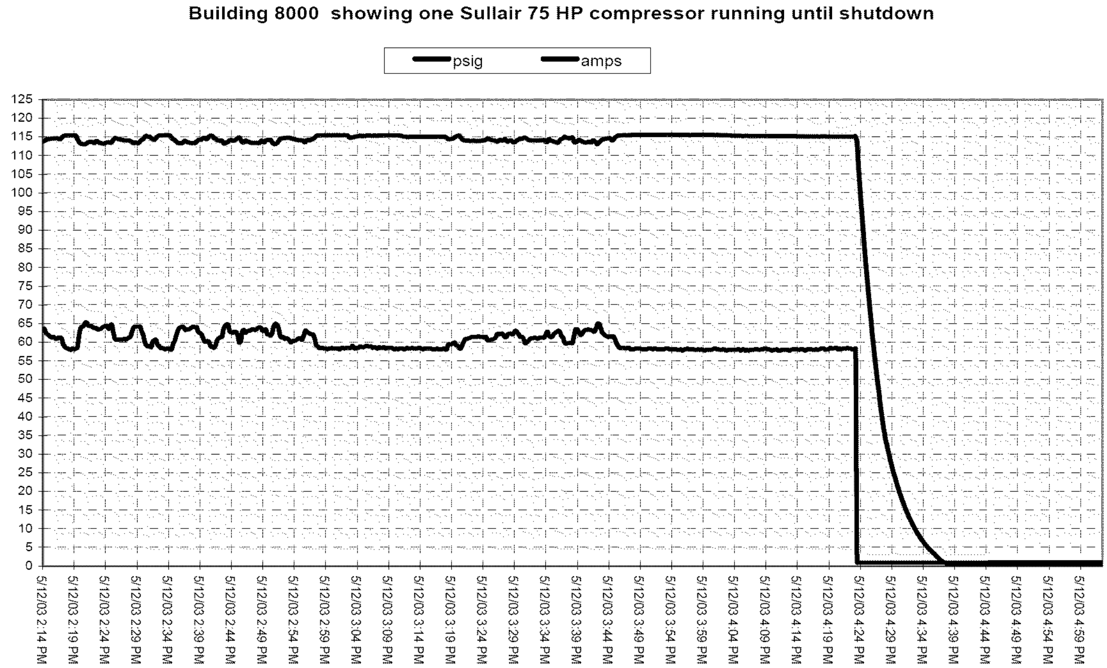
Demand is what really causes the plant's power meter to turn. It is the actual point-of-use, whether it is leaks, pneumatic tools, hoists, cylinders, blow-offs or diaphragm pumps. If the compressed air is never removed from the system, the pressure would remain stable and there would not be a reason for the compressor to turn on. Demand drives the system and the compressor reacts. Therefore, effective energy reduction starts with demand.

Demand at Fort Carson

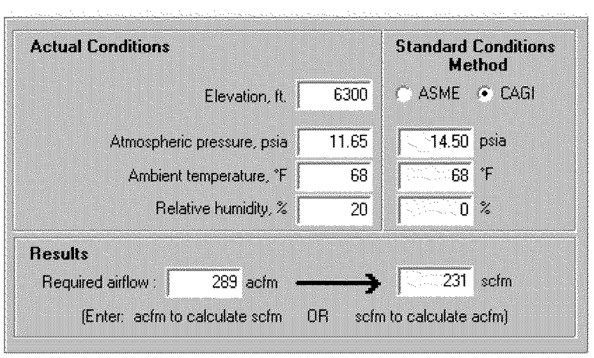
Determining the true demand at a facility is very important and can be difficult. Air demand fluctuates significantly and frequently exceeds any predetermined average demand. This assessment was not intended to identify all demands, given the short duration of the assessment. However the information does represent typical production routines. Therefore data is extrapolated and the results may still be fairly accurate. Only a full audit would identify and quantify all demands for Fort Carson.

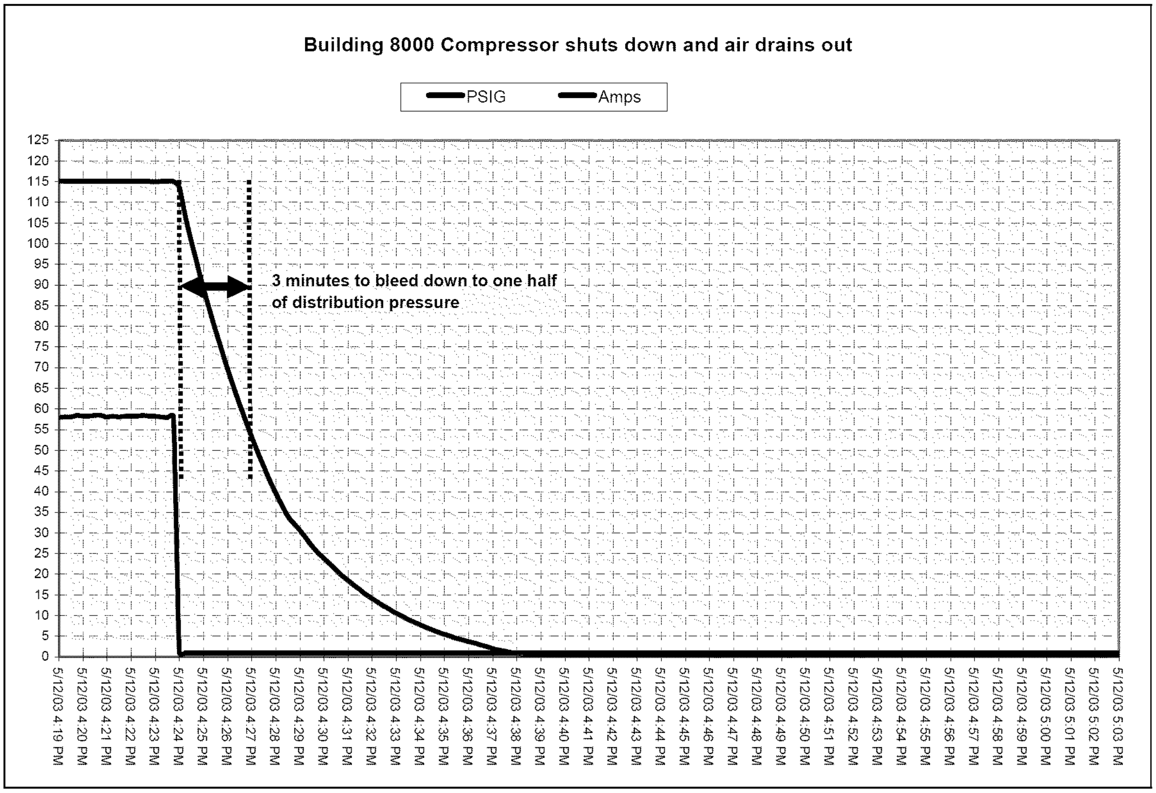
With over 40 buildings utilizing compressed air, the identification of each demand would be quite time consuming. Instead the types of air usage can be grouped together because all the buildings have the same issues regardless of their specific processes.

Types of Air Usage	Issues
Motor pool buildings with rotary screw compressors	All rotary compressors I observed had no automation to turn them off when they ran unloaded for extended time.
Motor pool buildings with reciprocating compressors	All recips utilized a pressure switch with start/stop as a means of control. This is a good energy efficient way to run a system with intermittent loads.
HVAC requirements	The compressors that run these systems are usually duplex tank mounted. They are also under a start/stop control and are only operating when needed.
Shop air	Utilize small recips with a pressure switch with start/stop as a means of control. This is a good energy efficient way to run a system with intermittent loads



The chart above shows a typical rotary screw compressor operating with minimal flow requirements from building 8000. The compressor was throttled back to 40% output. (Identified by position of inlet valve linkage). The scfm output of this compressor based on 6300 foot altitude is 231. The power required was 80-85% of full load requirements. I estimate that 90% or 200 scfm was leakage. If this occurs all year long, the leakage in building 8000 could cost $ 11,000 per year. The chart on the next page shows this pictorially.





When the compressor is shut off in building 8000, the pressure which was at 115 psig rapidly falls. Within 3 minutes the pressure has fallen to 55 psig.

Leakage is estimated in this system based on the bleed down rate of the piping and the receiver. This method requires an estimate of total system volume, including any downstream secondary air receivers, air mains, and piping (V, in cubic feet). The system is then started and brought to the normal operating pressure 115 psig (P1) and the compressor is turned off. This is shown on the above chart.

Solving for Leakage with Just the 900-Gallon Tank

Measurements show 3 minutes was the time (T) it took for the system to drop to a lower pressure (P2), which was equal to about one-half the operating pressure (55psig). Leakage is then calculated as follows:

Leakage (cfm free air) = [V x (P1-P2)/T x 11.65]

where:

V is in cubic feet (900 gallon tank = 120 cu. ft.)
P1 and P2 are in psig (115 – 55)
T is in minutes = 3

Nearly all the flow from the one online compressor was feeding leaks in building 800 while data was being logged. Again, leakage of greater than 10% indicates that the system can likely be improved. These tests should be carried out once a month as part of a regular leak detection and repair program.

Leaks

Annual energy cost to Fort Carson of $ 60,000 or 1,200,000 kWh

- Air leakage: can be defined as consumed air that contributes nothing to production.
- A typical plant that has not been well maintained will likely have a leak rate equal to 30% of total compressed air production capacity.
- On the other hand, proactive leak detection and repair can reduce leaks to less than 10% of compressor output.
- If you can't feel it or hear it, that's about $ 500 per year
- If you can feel it and hear it, that's about $ 2,000 per year
- Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production.
- By forcing the equipment to cycle more frequently, leaks shorten the life of almost all system equipment (including the compressor package itself).
- Increased running time can also lead to additional maintenance requirements and increased unscheduled downtime.
- Finally, leaks can lead to adding unnecessary compressor capacity.
- The best way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high frequency hissing sounds associated with air leaks.
- All facilities with compressed air systems should establish an aggressive leak program.

How To Conduct an Air-Leak Survey

Learning how to conduct an in plant air-leak survey is simple. A variety of tools using airborne ultrasound technology allow inspectors to detect deteriorating components and repair them before they fail. The results are startling, and the impact on the company's bottom line will impress top management.

All operating equipment should be checked every 3 months. The best plan is to inspect the entire plant department by department, always following the same pattern. However, if such a program seems too daunting, a plant might limit periodic inspections to one or two departments. As maintenance crews become more familiar with ultrasound and inspection techniques, the survey can be expanded to include the entire operation.

Air-leak inspections can be conducted with the equipment on or off. As a rule, technicians begin by determining at what kinds of loads the air compressors are operating. They use the ultrasound instrument to establish sound patterns of properly operating equipment. It is important to slowly scan the entire air-line system.

The technician aims the ultrasonic scanner directly at the part of the machine under inspection and makes small cross-pattern movements along all exposed sections. The more sensitivity levels the instrument has, the better it performs. If, for example, a 1 in. pipe is suspected of leaking, the technician should wave the gun an inch or two in each direction, moving parallel to the pipe until finding the leak. Then the instrument's close focus adapter can be honed in on the exact location of the leak. The problem may actually be in the fitting.

A special scanner can be used to test equipment up to 100 ft away. When testing for leaks in air or blow-off applications near open air tubes, for example, the technicians must focus the scanner away from interfering noise and isolate the ultrasonic sounds.

Every leak should be tagged with the location and an identification number. A note should also record a description of each leak, including the size. The make and serial number of equipment such as quick couplers, filters, regulators, and lubricators that may be causing a chronic leakage problem should be recorded so as to avoid purchasing the part again.

The technician should double-check each leak that is repaired before moving on to the next area. Often new leaks are inadvertently created during the repair stage and go unnoticed because the part is not retested. Using confirmation and shielding techniques, such as sealing, always pays off when the entire connection is checked one final time.

Artificial Demand

Someone needs to prove that over 90 psig is needed anywhere in the entire facility. The higher pressure is causing all unregulated air using devices to consume more compressed air than required. This is called artificial demand and as noted is costing Fort Carson an additional 10% of energy annually. This extra flow just adds to the compressor requirements.

(Artificial Demand = additional air consumption caused by excessive system pressure. Meaning if a certain mass of air can flow through an opening at a given pressure, then the laws of fluid dynamics state that more mass will flow

through that same opening at elevated pressures. At the majority of buildings I visited, there are very few regulators that were set to control at a lower pressure. Since the header pressures or compressor discharge pressures I observed were running about 10 to 20 psig above where they needed to be, there will be a corresponding increase in flow of almost 10-20%. This equates to additional compressor capacity that needs to be online at Fort Carson.)

The chart below shows just how much more scfm can flow through any given orifice size as the pressure increases. Unless there is a regulator installed at every point of use, the existing distribution pressure will determine the flow rate.

Discharge of Air Through an Orifice in SCFM

Gauge Pressure at Orifice	1/32	1/16	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
30	0.633	2.53	10.10	40.50	91	162	253	365	496	648
35	0.703	2.81	11.30	45.00	101	180	281	405	551	720
40	0.774	3.10	12.40	49.60	112	198	310	446	607	793
45	0.845	3.38	13.50	54.10	122	216	338	487	662	865
50	0.916	3.66	14.70	58.60	132	235	366	528	718	938
60	1.06	4.23	16.90	67.60	152	271	423	609	828	1082
70	1.20	4.79	19.20	76.70	173	307	479	690	939	1227
80	1.34	5.36	21.40	86	193	343	536	771	1050	1371
90	1.48	5.92	23.70	95	213	379	592	853	1161	1516
100	1.62	6.49	26.00	104	234	415	649	934	1272	1661
110	1.76	7.05	28.20	113	254	452	705	1016	1383	1806
120	1.91	7.62	30.50	122	274	488	762	1097	1494	1951
125	1.98	7.90	31.60	126	284	506	790	1138	1549	2023

Addressing the issue on high pressure:

- Regulate all point-of-use operations at the lowest possible pressure using a quality regulator: Each and every point-of-use in the plant needs a regulator. Consider a cylinder that is supposed to operate at 85 psig, but instead is filled by air at a line pressure of 110 psig. Twenty five percent more molecules are required to fill that cylinder at 110 psig versus 85 psig. (The percentage is determined by the ration of the density of the gases.) This 25 percent greater "artificial" demand forces the compressor to operate for a longer period of time to suck in those molecules. This would hold true for any point-of-use that is either unregulated or is not regulated to its lowest possible pressure. Be sure to use a quality regulator, as poor quality regulators tend to drift and track. If the regulator tracks or drifts up five psig, then the application will use more air.
- All too often FRL's, quick disconnects and process feed lines are selected on the basis of size, convenience and price, with little or no regard for flow and allowance for pressure drop. The cornerstone of any effective compressed air

energy savings program applied to the distribution or process side is to identify the lowest effective pressure that runs the process at optimum performance. The key is to deliver the air at the lowest possible cost using every variable you have—piping, connection, pressure flow controls, appropriate storage and so forth.

- Remember, pressure costs money in two ways—power to produce increased pressure costs one half of one percent per psi, and excess pressure produces excess flow that must be compressed.*

Inappropriate Uses

Compressed air generation is one of the most expensive processes in an industrial facility. When used wisely, compressed air can provide a safe and reliable source of power to key industrial processes. Users should always consider other cost-effective forms of power to accomplish the required tasks and eliminate unproductive demands. Inappropriate uses of compressed air include any application that can be done more effectively or more efficiently by a method other than compressed air.

- Unregulated end uses: operation of tools without pressure regulators leading to an overall higher system pressure requirement.
- Abandoned equipment: air flow to equipment that is no longer in use either due to a process change or malfunction.

Compressed air is obviously a necessary part of Fort Carson's operations, but it is also the most inefficient source of energy in the plant.

To operate a 1 hp air motor, you need 7-8 horsepower of electrical power into the compressor. At higher than typical pressures, even more power is needed.

- 30 scfm @ 90 psig is required by the 1 hp air motor
- 6-7 bhp at compressor shaft is required for 30 scfm
- 7-8 hp electrical power is required for 6-7 bhp at shaft

The overall efficiency of a typical compressed air system can be as low as 10-15 percent.

* For systems in the 100 psig range, for every 1 psi increase in discharge pressure, power use will increase by approximately 1/2 percent at full output flow.

Annual energy costs for a 1 hp air motor vs. a 1 hp electric motor, 8760 hours per year based on $0.05/kWh.

$2,900 (compressed air) vs. $363 (electric)

(Compressed air should not be thought of as free.)

Transmission at Fort Carson

The ideal distribution system provides a sufficient supply of compressed air at the required pressure to all of the locations where compressed air is needed. The flow of compressed air in pipelines creates friction and results in pressure drop. Pressure drop in the pipeline should ideally by no more than one to two psig.

Where practicable, the distance from the air compressors to the points of use should be minimal. The longer the piping runs, the greater the pressure drops and the increase in energy consumption. Long piping runs also aggravate pressure fluctuations caused by intermittent demands at various locations. Since there was such minimal flow occurring in any of the buildings I was in, the ability to determine pressure drops was not possible. The piping that I observed was more than adequate to handle all flows throughout the facilities.

The Compressed Air & Gas Handbook has tables of pressure losses (psi) due to friction in piping, for various rates of flow and pressure. The following table is for an initial pressure of 100 psig and demonstrates the need for adequate pipe sizes:

Cu. Ft Free Air Per Min.	Equivalent Cu. Ft. Compressed Air Per Min.	Pipe Diameter - Inches						
		1	2	3	4	6	8	10
10	1.28	0.28						
50	6.41	9.96	0.19					
100	12.82	27.9	0.77					
250	32.04		4.78	0.58				
500	64.28		19.	2.34	0.5			
750	96.13		43.3	5.23	1.2			
1000	128.2		76.9	9.3	2.2			
1500	192.2			21.0	4.9	0.56		
2000	256.3			37.4	8.8	0.99		
2500	316.4				13.	1.57	0.37	
3000	384.6				20	2.26	0.53	
4000	512.4				35.	4.01	0.94	0.
5000	632.8				55.	6.3	1.47	0.

Pressure Drop Due to Friction

In psi in 1000 ft. of pipe, 100 psig initial pressure.*

Supply at Fort Carson

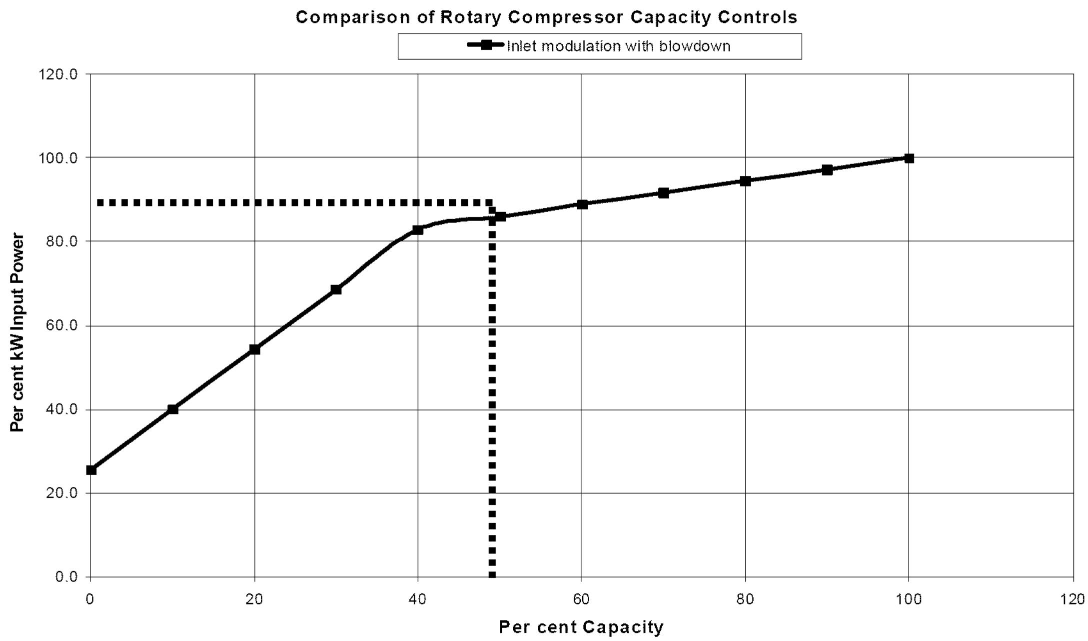
Compressed air supply is provided by air compressors. The compressed air supply, utilizing sufficient storage, and proper distribution, must meet the compressed air demand. If supply, storage and distribution are not in tune or aligned, excessive pressure fluctuations will occur resulting in increased operating costs. Most compressors ability to load or unload is controlled by line pressure. Typically a drop in pressure indicates an increase in demand. This then causes a compressor to come on line or load and thus handling the increase in flow.

At Fort Carson, all recipients that I saw were operating in a start/stop mode. When pressure was satisfied they would shut off. This method of control is excellent for smaller hp compressors and intermittent loads. The rotary screw compressors however only have a start and stop button. They are missing what is known as “Dual Control” which will allow them to time out and shut

* Pressure drop is directly proportional to length of pipe.

off (once the compressor unloads) after a pre-set amount of time. Without the dual control option the flowing scenario occurs:

1. The compressor still has the ability to unload where it will drops its power requirement to approximately 30% of its full load power
2. It will stay unloaded until the pressure switch closes do to a pressure drop.
3. It cannot shut down atomically. It must be physically shut down by pushing he stop button.
4. Because of the excessive leak rate in all buildings, the compressors never unload. It throttles back its flow to match the demand which is primarily leaks.



This chart shows the power required by the motor of a suction throttle compressor operating at part loads. The rotary screw compressors at Fort Carson are all operating with this type of control. At a 40 to 50% load, the compressor is still at an 80 to 90% power requirement. If the leaks can be repaired, then the compressor will have a chance to unload where its power will drop considerably. The dual control will allow it to time out and shut down.

Energy and Quality Improvements Itemized

Item	Issue	Consumed	Proposed	Materials/Labor	Savings
Leaks	Loss of compressed air. Excessive flow through pipes causing more pressure drop	$60,000 annually	Institute leak prevention program	Leak detector tool costs $ 3,000 One man day per building every 90 days	Minimally $ 30,000/yr (600,000 kWh/yr) if only 50% are repaired
Screw Air Compressors without auto shut down controls	Potential for a compressor to run 24/7 unless someone shuts them off	$ 29,000 annually based on my 24 hours of observation	Install a "Dual Control" Kit in each rotary screw compressor.	Examples of kits: For Sullair 10-30 p/n 250025-721 $ 544.50 each For Sullair 16-75 p/n 250025-722 $ 550.50 each Contact local vendor for more specifics	If leaks are contained, there cold be an additional $29,000 (580,000 kWh/yr) savings from compressors unloading and shutting down
Operating at a higher than needed pressure – Artificial Demand *	Excess HP online and excess flow as a result	10-20% more scfm more than required	Lower pressure by at least 10-20 psig. This will result in a 5 - 10% energy reduction in each building.	No materials and about 1 man hour of labor per building. First you must determine what the lowest acceptable pressure is.	1% energy reduction for every 2 psig reduction.
*Artificial Demand = additional air consumption caused by excessive system pressure. Meaning if a certain mass of air can flow through an opening at a given pressure, then the laws of fluid dynamics state that more mass will flow through that same opening at elevated pressures. If you lower the pressure the flow will be less and the end result is a compressor loaded less.					

Implementation Steps

1. Start leak detection and repair program for all buildings.
   a. Start with one man day per building (larger buildings) and 90 day intervals
   b. Typical leak detector for compressed air
      (1) UE systems is a good start www.uesystems.com
2. Install the appropriate automation in each rotary screw compressor that lacks it.
   a. The kit number and pricing should be obtained from your local compressor vendor.
   b. Typical kit pricing is approximately $ 550 each
3. Identify what each buildings pressure requirements really are.
   a. Make sure they are valid requirements and not just someone's opinion.
   b. Try 5 psi at a time until optimum lowest allowable pressure is reached.

Collaborative Targeted Assessment Summary

Company	Fort Carson	CTA Date	5/12/03	
Plant	Fort Carson, Colorado	Component		
Product		Evaluator(s)	Frank Moskowitz 480 563-0107	
Plant Contact Information				
Name	Scott Clark			
Address	1638 Elwell Street			
City/State	Fort Carson, CO			
Phone	719 526-1739			
e-mail	Scott.Clark/URS@carson.army.mil			

Summary Information

	Savings/yr			
Finding	**$**	**kWh**	**MBtu**	**Fuel type**
Leaks	60,000	1,200,000		
Lack of compressor controls	29,000	580,000		
Artificial Demand				

Administrative Issues

At Fort Carson, management needs to review the requirements of the compressed air at each building as it is currently used. They need to access their development plans to see if processes might change that could reduce the air requirements. Consider using an appropriate mix of compressed air, blowers, hydraulics, and electric's, since the best power option may vary from one piece of equipment to another. Each buildings occupant need to understand the associated expense of the compressed air being used. It is possible to save 25-50 percent of the energy consumed by a compressed air system, but to do so; the focus must start with the points of use.

"If the air is never consumed, then it never has to be replaced."

While the points of use drive the system, the piping system should exist to get the air to the point-of-use when it needs it. And while the points of use are the real reason for the energy consumption, all the actions you take at the points of use result in the power meter in the compressor room turning more slowly. And the final savings are realized by efficiently replacing the air already removed by the

system. If the losses of air due to leaks are modified, then the online horsepower can be reduced significantly.

All too often FRL's, quick disconnects and process feed lines are selected on the basis of size, convenience and price, with little or no regard for flow and allowance for pressure drop. The cornerstone of any effective compressed air energy savings program applied to the distribution or process side is to identify the lowest effective pressure that runs the process at optimum performance. The key is to deliver the air at the lowest possible cost using every variable you have—piping, connection, pressure flow controls, appropriate storage and so forth.

Note: when purchasing compressed air equipment, the lowest price for an air compressor may save money up front but over the life of the compressor can be a very expensive mistake. Over the life of a system, the energy costs far exceed any of the other costs.

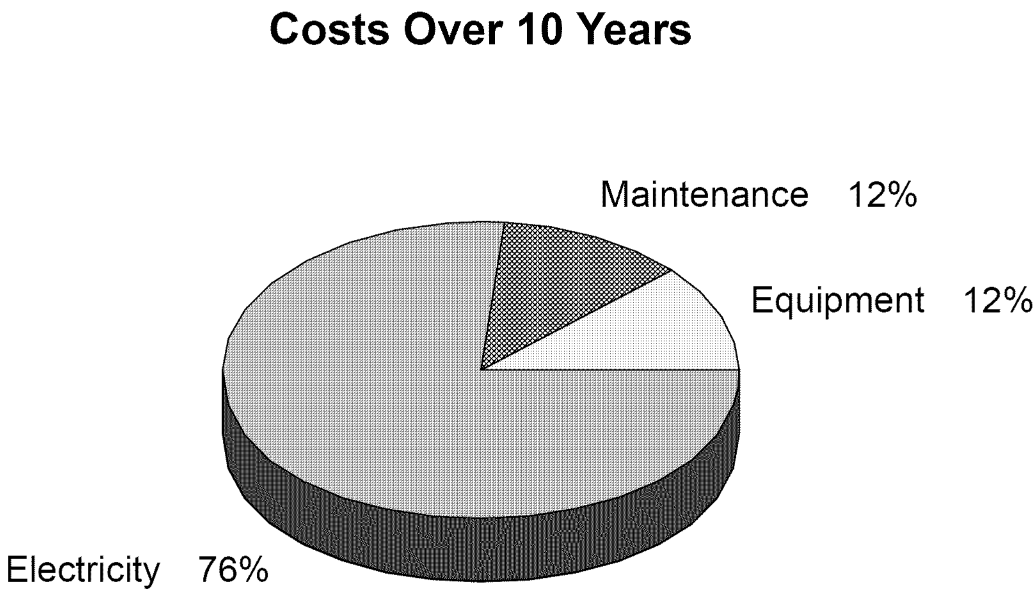
Year	Equipment	Maintenance	Electricity
1	$ 20,000	$ 2,000	$ 13,000
2		$ 2,000	$ 13,000
3		$ 2,000	$ 13,000
4		$ 2,000	$ 13,000
5		$ 2,000	$ 13,000
6		$ 2,000	$ 13,000
7		$ 2,000	$ 13,000
8		$ 2,000	$ 13,000
9		$ 2,000	$ 13,000
10		$ 2,000	$ 13,000
Total	$ 20,000	$ 20,000	$ 130,000

Simplified example:

75 hp compressor (capital cost = $20,000)

5-day per week, 2-shift operation

Electricity costs of $0.05/kWh (annual cost = $13,000)



Remember: if maintenance and equipment is reduced or ignored, the electricity portion of this energy pie will get even larger!

The success of the survey was due to people at Fort Carson and LB&B who assisted in the process. All were very willing to answer questions and take time out of their busy schedules. Their help was essential in understanding and resolving the many complex issues associated with this type of industry. I offer a big Thank You to everyone involved.

Any questions concerning the findings or subsequent recommendations should be addressed to Frank Moskowitz at (480) 563-0107. Thank you.

Helpful Hint Topics

Leaks

Sometimes it can feel almost intimidating to start a compressed air leak detection and repair program. The best way is to follow these simple steps:

1. Walk through your plant. While you walk, pay attention to obvious problems such as loud leaks that you can spot and tag without the aid of an ultrasonic detector. Observe misuse of air such as valves left wide open, rags placed over

pipes to reduce the noise level of large leaks, unattended machines left on with air blowing all over the place.
2. As you walk, try to determine the best route for inspection.
3. If possible, take a print of the compressed air piping system, or make a simple sketch. These graphics will help you identify the leaks and make it easier to find them for repair.
4. For consistency, start at the compressor/supply side and work your way to the use or demand side.
5. When you begin your inspection, create a series of inspection "zones." This will help organize your approach and prevent the possibility of overlooking a section and missing some leaks. Move from one "zone" to the next in a planned organized manner.
6. Tag all leaks. The tag will make it easy to spot the leaks for repair.
7. Test all leaks after they have been repaired. Sometimes leaks can be fixed and new ones created inadvertently.
8. Calculate your savings using cfm charts and formulas
9. Report your results. Let management know what a great job you're doing.
10. Help Others with Your Compressed Air Experience

Checklist items

The following are checklist items, which can aid you in identifying compressed air applications in your systems that can lead to poor system performance and excessive energy costs:

- High end-use pressure requirements
  - Are end use pressure requirements true or assumed?
  - How are the pressure setpoints of the compressors configured?
  - Are the compressors operating at a much higher pressure than end use requires?
- Which areas of the plants end users are complaining about low pressure?
  - Is the low pressure in the header or at the point of use?
  - Have the compressor setpoints been raised to compensate for the low pressure at the end use application, or has the low-pressure condition been explored?
- Which applications use high volumes of compressed air for a short duration
  - Identify minutes or seconds of (on and off time)
  - Have any steps been taken to using storage to address these applications?
- Are there opportunities to reduce leaks in the system?
- Is air quality an issue?
  - Compressed air should be treated only to the level required for each point of use application.

- Is compressed air being used inappropriately? The following is list of potentially inappropriate uses:
  - Open blowing
  - Sparging (agitating, stirring, mixing)
  - Aspirating
  - Atomizing
  - Padding
  - Dilute and Dense phase transport
  - Vacuum generation
  - Personal Cooling
  - Open hand held blow guns or lances
  - Cabinet cooling
  - Timer drains/open drains for condensate
  - Air motors

Maintenance

Like all electro-mechanical equipment, compressed air systems require periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. Inadequate maintenance can have a significant impact on energy consumption via lower compression efficiency, air leakage, higher operating temperature, poor moisture control and excessive contamination. Most problems are minor and can be corrected by simple adjustments, cleaning, parts replacement, or the elimination of adverse conditions.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
11-2003	Final	

4. TITLE AND SUBTITLE
Process Optimization Assessment:
Fort Leonard Wood, MO and Fort Carson, CO

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Mike C.J. Lin, John Vavrin, Walter Smith, and Clay Conner

5d. PROJECT NUMBER
622784AT45

5e. TASK NUMBER
CFE

5f. WORK UNIT NUMBER
CFE-X302

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-03-23

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Fort Leonard Wood
1338 First Street
Building B2101
Fort Leonard Wood, MO 65473

Fort Carson
1638 Elwell Street
Fort Carson, CO 80913

10. SPONSOR/MONITOR'S ACRONYM(S)
DPW

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

This work performed a Process Optimization Assessment (POA) on behalf of Fort Leonard Wood, MO and Fort Carson, CO to identify process, energy, and environmental improvements that could significantly improve the installation's mission readiness and competitive position. A Level I assessment assumes that technical solutions are possible and that economics are approximations. No engineering measurements are made. The existing process is challenged, and new practices and new technologies are considered. A Level I assessment would normally be followed by a Level II process audit (an in-depth analysis in which all assumptions are verified), which would result in a group of "appropriation grade" process improvement projects for funding and implementation.

This work quantified 26 Energy Conservation Measures (ECMs) at Fort Leonard Wood, which, when implemented, will reduce the post's annual energy and operating costs by approximately $1,963,275 for a capital investment of approximately $1,929,300, yielding an average simple payback of 1 year. When implemented, the 29 ECMs quantified at Fort Carson will reduce that installation's annual energy and operating costs by approximately $2,117,250 for a capital investment of approximately $1,250,300, yielding an average simple payback of 0.6 yr.

15. SUBJECT TERMS
energy conservation
Fort Carson, CO
Fort Leonard Wood, MO
pollution control
process optimization (PO)
process energy and pollution reduction (PEPR)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Mike C.J. Lin
Unclassified	Unclassified	Unclassified	SAR	208	19b. TELEPHONE NUMBER (include area code) 217-352-6511, X-7358